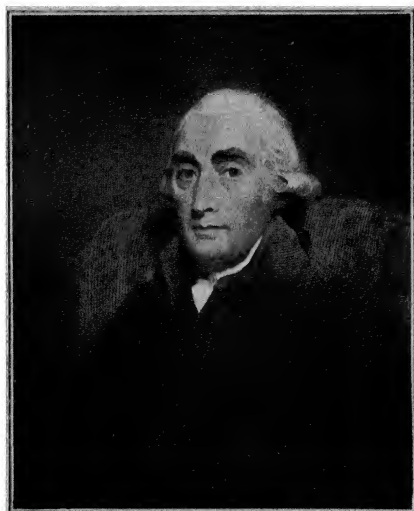


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**THE LIFE AND LETTERS OF
JOSEPH BLACK, M.D.**



JOSEPH BLACK, M.D.

From a print by A. Heath, after a portrait by Raeburn

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**THE
LIFE AND LETTERS
OF
JOSEPH BLACK, M.D.**

**BY
SIR WILLIAM RAMSAY
K.C.B., F.R.S.** —

**WITH AN INTRODUCTION
DEALING WITH THE LIFE AND WORK OF
SIR WILLIAM RAMSAY
BY
F. G. DONNAN, F.R.S.**

**LONDON
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INTRODUCTION

SIR WILLIAM RAMSAY

SIR WILLIAM RAMSAY was born in Glasgow in 1852. His paternal grandfather was a dyer at Haddington, who in 1780 became a partner in the firm of Arthur & Turnbull, Camlachie, manufacturers of chemicals used by dyers. As Sir William Ramsay has himself related, it is probable that both potassium bichromate and the well-known "Turnbull's Blue" were discovered by his grandfather. He appears to have been well known to many celebrated French chemists of his day, such as Gay-Lussac, De Morveau, and Vauquelin. He died in 1827, leaving three sons and a daughter—Andrew Ramsay, who afterwards became Sir Andrew Ramsay, F.R.S., head of the Geological Survey of Great Britain; John Ramsay, who became a sugar manufacturer in Demerara; William Ramsay, the father of Sir William Ramsay; and Eliza Ramsay, who was an enthusiastic worker in field botany. William Ramsay was trained as an engineer, and took part in the great railway development of the period. He possessed a good knowledge of science and mathematics, and spent the later years of his life as a local manager of the Scottish

Union Assurance Company. On the side of his mother, Catherine Robertson, Sir William Ramsay was descended from an Edinburgh family which had, for several generations, produced medical men of note.

After having studied at a preparatory school and at the Glasgow Academy, Sir William Ramsay matriculated in the University of Glasgow in November, 1866, at the age of fifteen. His first years at the University were spent, after the Scottish fashion of those days, in the study of classics, general literature, logic, philosophy, and mathematics. Turning to science in 1869, he began the study of practical chemistry in the laboratory of Robert Tatlock. During this period he came under the influence of Anderson in chemistry and Sir William Thomson in physics. Having decided on chemistry as a profession, he went to the laboratory of Professor Fittig at Tübingen in 1871, where after two years' work he obtained the degree of Ph.D. for a research on toluic acid. Returning to Scotland, he became at first assistant in The Young Laboratory of Technical Chemistry under Bischof, and then, in 1874, assistant to Professor Ferguson in the University of Glasgow.

In 1880 he was appointed Professor of Chemistry at University College, Bristol, where soon afterwards he also became Principal. He remained seven years at Bristol, doing an immense amount of research, teaching, and administrative work, and contributing greatly to the development and prestige of what was then a

struggling and poorly financed provincial University College.

In 1887 Sir William Ramsay was chosen to succeed Professor Alexander Williamson in the Chair of Chemistry at University College, London. Here he worked until his retirement in 1912, and here all his greatest discoveries were made. His last few years were spent in the pleasant Buckinghamshire country, a few miles from High Wycombe, where he had built a chemical laboratory attached to his house, and, assisted by his son, was busily engaged on chemical researches when death overtook him in July, 1916, at the age of 64.

Sir William Ramsay's scientific work may be divided into five periods. The first period, 1874-80, was spent in the University of Glasgow. During this time he did a considerable amount of important work in the field of organic chemistry, including the production of various pyridinic acids from the pyridine bases which Professor Anderson had prepared many years previously, the synthesis of pyridine from hydrocyanic acid and acetylene, and the production of pyridine by the action of heat on the silver salts of the acids obtained by the oxidation of the alkaloids quinine and cinchonine—an important discovery, showing for the first time the relation of the alkaloids to their parent substance pyridine. Although overloaded with the heavy work of teaching large numbers of medical students, Sir William Ramsay found time not only to carry out original investigations himself but also

to encourage some of the senior students to undertake researches under his guidance. Amongst these may be specially mentioned J. J. Dobbie and A. Smithells.

It is interesting to observe that out of this early work at Glasgow grew Sir William Ramsay's predilection for physical chemistry. As he has himself related, his researches on the complex mixture of pyridine bases led him to adopt and modify methods for determining vapour densities, in order to help in elucidating the molecular weights of the substances involved. Having inherited a wonderful gift of manipulative skill and dexterity, combined with a practical genius for experimenting, he soon taught himself the art of glass-blowing and learnt to construct all his own apparatus. In this way he acquired an extraordinary power in the accurate manipulation of liquids, vapours, and gases—a power which increased with each research he undertook, and which was destined to play an important rôle in the famous discoveries of his later life.

In the second period (Bristol, 1880–87) Sir William Ramsay threw himself enthusiastically into the field of physical chemistry. Together with his assistant and collaborator, Dr. Sydney Young, he published numerous researches on vapour-densities, critical constants, evaporation, dissociation, etc., and devised and constructed many new forms of apparatus adapted to the investigation of liquids and vapours. In spite of the heavy calls on his time and strength made by his teaching and administra-

tive work, the researches published by Sir William Ramsay during the seven years at Bristol established his reputation as one of the most eminent physical chemists in Europe.

His scientific research work in London (1887-1916) may be divided broadly into three periods. In the first of these he continued the physico-chemical work which had occupied his attention at Bristol. Perhaps the most remarkable research of this period was his investigation (in collaboration with Dr. John Shields) on the molecular weights of pure liquids as deducible from the variation with temperature of their molecular "surface-energies." In the second period of his scientific work in London came the wonderful discovery of the series of "inert" elementary gases. Beginning with the discovery, in conjunction with Lord Rayleigh, of argon in atmospheric "nitrogen," and of helium in the gas evolved from the mineral cleveite on heating, Sir William Ramsay, with the imaginative insight of genius, perceived that these gases must belong to a new series or family of elements in the classification of Mendeléef.

All the accumulated skill and experience of many years of tireless research, all the courage, fire, and energy of a master mind at the zenith of its power, were thrown into action ; and ably supported by the skill and energy of his assistant, Dr. Morris William Travers*, one of his own students, Sir William Ramsay achieved one of the greatest triumphs that science can record, the discovery

of the elementary gases neon, krypton, and xenon—the missing members of the new group of elements that his genius had divined.

Coming now to the last period of Sir William Ramsay's work, the writer well remembers how one Monday morning he came down to the laboratory in a state of great excitement and made experiments to ascertain whether argon and helium would discharge an electroscope. What did it all mean, we wondered? Rutherford and Soddy in Canada had just published a paper in which they had demonstrated that the radio-active "emanation" was really a gaseous substance—but one that had no power of chemical combination! Ramsay's mind had again leapt across the gulf of the unknown with the instinctive vision of genius. Soon came his discovery, in collaboration with Dr. Soddy, that the element radium was constantly being transmuted into the element helium. The theory of radio-activity put forward by Rutherford and Soddy was proved to be correct, and the first definitely recognisable transmutation of the chemical elements was established on a firm experimental basis. Sir William Ramsay now entered the new field of radio-active transformation with characteristic energy, but also with characteristic originality. Just as Sir Humphry Davy about a hundred years previously had made use of the then newly discovered and powerful weapon of the voltaic electric current to decompose the "elements" potash, soda, lime, etc., so Sir William Ramsay employed the torrent of

kinetic energy set free in the transformation of radium emanation to attempt the decomposition of our present-day stable elementary substances. The results which he obtained have been criticised, and in part contradicted by the results of other investigators. On this matter we may safely leave the final decision to the future. Whatever the judgment on matters of detail may be, the attempt which Sir William Ramsay made was characteristic of his daring and original genius, and will some day prove to be, if not the final solution of the problem, at all events much nearer to it than anything attempted by his contemporaries.

One of the last great researches which he undertook was the determination of the density of niton, the gaseous "emanation" of radium. In this work, carried out in collaboration with his assistant and former pupil, Dr. Whytlaw-Gray, Sir William Ramsay's experimental genius reached its culminating point. What other man could have successfully determined, or even attempted to determine, the density of 0.005 cubic millimetre of an unstable gas !

It is seldom, however, that really great achievement in any sphere of life is due to the possession of a single quality. Wonderful as was Sir William Ramsay's experimental skill, this formed but a small part of his rich natural endowment. Above all, he was the great investigator, full of rare intelligence, insight, imagination, and curiosity. Combined with these qualities he

possessed in high degree a daring originality of thought, and a courageous and sanguine temper of mind that difficulty only spurred to higher effort. Last but not least, his tireless energy extracted the maximum work out of every day by means of his exceptional power of instant action. Nothing was ever postponed. What, an ordinarily very active man would do on Monday morning Sir William Ramsay did on Saturday afternoon.

To the very end of his life he retained that wonderful freshness of mind and receptivity for new facts and ideas which were two of his most distinguishing characteristics. Of him one might truly say that "age could not wither nor custom stale his infinite variety."

The amazing quickness and perpetual activity of his mind were most extraordinary. It is difficult to believe that there were many moments when no new thoughts or ideas were fermenting in his brain. Thus Sir William Ramsay was a constant source of inspiration to his students. Fired as they were by the great example which he set of a life devoted to scientific investigation, their minds were spurred to action by constant association with a mind of unequalled freshness, originality, and power.

It is hard to find words adequate to describe Sir William Ramsay's rare personal charm. In him a keen wit and a rich humour were combined with broad human sympathy. The warm blood that coursed

through that active brain was pulsed by the kindest of hearts. To his students past and present he was ever the sincerest and most accessible of friends. The honours which the world hastened to lay at his feet never changed him, never altered the gentle quality of his spirit. The great things he did never lessened his sympathy and understanding for the less gifted. He was indeed a great gentleman as well as a great man.

Possessed of an excellent and well-stored memory and a fine sense of humour, Sir William Ramsay could tell an anecdote or story in the most delightful way, and was an excellent and witty speaker both in public and in private. He could sing a song well and play his own accompaniment. He could converse freely in several foreign languages. Who that knew him can ever forget the irresistible attraction of his personality, the magic of the smile that flashed so often from a face illumined by the high intelligence of a great mind and the radiance of a warm heart? The unaffected friendliness and the almost boyish vigour and eagerness of his spirit never deserted him. His was a unique and endearing personality.

In Sir William Ramsay the great tradition of British "pneumatic chemistry" reached its crowning glory. It is remarkable how many great British chemists have shown pre-eminent ability in the investigation of the nature of gases. To appreciate the truth of this state-

ment one has only to recall the names of Hales, Mayow, Boyle, Black, Priestley, Cavendish, Dalton, Humphry Davy, and Graham. In the seventeenth century John Mayow gave striking evidence of that practical genius in the investigation and manipulation of gases which in the case of Sir William Ramsay was developed to the highest pitch of perfection and refinement of technique. The investigation of the "fixed air" whose presence differentiates the "mild" from the "caustic" alkalies played a fundamental rôle in the work of Joseph Black. This exact quantitative work of Black's must have appealed strongly to Sir William Ramsay, who in his remarkable book on "The Gases of the Atmosphere" has given a most masterly account of the main work of the "pneumatic" chemists.

It was Sir William Ramsay's custom for many years to lecture once a week during the summer term on the history of chemistry. He possessed an excellent and first-hand knowledge of the subject, and held very strongly that all students of chemical science should make themselves familiar with the fundamental researches on which their science was founded. Many generations of students remember with gratitude these lectures of Sir William Ramsay's, from which they invariably derived the greatest pleasure and profit.

The classic work of Joseph Black inaugurated the modern period of the quantitative study of chemical reactions. It was this classic investigation which Lavoisier, as he has

himself confessed, took as his model. We may indeed regard Black's work as constituting the beginning of modern chemical science.

Sir William Ramsay possessed an intimate knowledge of this work, and as they were both alumni of the same alma mater (the University of Glasgow) it was exceedingly appropriate that he should write an account of Black's life and work. He had already shown in his "Gases of the Atmosphere" what a deep sense he possessed for the significance and value of the historical treatment of science. The present work is another striking example of this historical perception; and constitutes in a certain sense not only a very charming act of piety, but also the tribute paid by one great mind to the memory of another.

Chemical science has traversed a long road in the period between "fixed air" and argon. But the great investigators and discoverers remain the same, and the mantle so greatly and honourably worn by Ramsay was none other than the mantle of the great and gentle Joseph Black.

F. G. DONNAN.

THE LIFE AND LETTERS OF JOSEPH BLACK, M.D.

CHAPTER I

THERE are some natures so happily constituted that they escape many of the trials which beset most men. Marcus Aurelius thanked his adopted father for having taught him the advantages of "a smooth and inoffensive temper; constancy to friends without tiring or fondness; being always satisfied and cheerful; reaching forward into the future, and managing accordingly; not neglecting the least concerns, but all without hurry, or being embarrassed." Such a character had Joseph Black. Dr. Robison, the editor of his lectures, his successor in Glasgow College, and his biographer, wrote: "As he advanced in years, his countenance continued to preserve that pleasing expression of inward satisfaction, which, by giving ease to the beholder, never fails to please. His manner was perfectly easy and unaffected, and graceful. He was of most easy approach, affable, and readily entered into conversation, whether serious or trivial. His mind being abundantly furnished with matter, his conversation was at all times pertinent

and agreeable. He was a stranger to none of the elegant accomplishments of life." His friend, Dr. Ferguson, said of him : " As Dr. Black had never anything for ostentation, he was at all times precisely what the occasion required, and no more. Never did anyone see Dr. Black hurried at one time to recover matter which had been improperly neglected on a former occasion. Everything being done in its proper season and place, he ever seemed to have leisure in store ; and he was ready to receive his friend or acquaintance, and to take his part with cheerfulness in any conversation that occurred." His successor, Dr. Thomas Thomson, found Dr. Robison's estimate of Black's character so just that he appropriated it almost verbatim in his *History of Chemistry* without the formality of quotation marks.

Black himself, it will be seen, began a new epoch in Chemistry and Physics, by his fundamental work on Heat, and on the nature of chemical combination ; and his name must ever remain associated with those of other illustrious Scotsmen of his day as one who led the way in chemical research and its technical applications.

Of Joseph Black's ancestry there is little to tell. " There is a tradition that a son of the Laird of Lamont had remarkably black hair. He was called Gillie-dhu, and his sons Macgillie-dhu, ' sons of the black servant.' Some of them settled on the North Coast of Ireland, whence some of their descendants came to Belfast and settled there. They anglicised their name to Black.

" Sir John Eccles of Orange-Grove, about two miles from Belfast, had three daughters. Jean married Mr.

Black of Belfast. Their son John went to Bordeaux, and settled there as a wine-merchant. He married Margaret Gordon of Houghhead in Aberdeenshire. A sister of Miss Gordon married James Russell, and another, Ferguson. Their sons were Joseph Black, Adam Ferguson, and James Russell.

“The Revd. G. M. Black’s grandfather was George Black, senr. of Belfast. He and his brother Samuel were ‘sovereigns’ of Belfast [i.e. Mayors]. Joseph Black used to say that his brother George would have surpassed him if he had been allowed to follow the bent of his mind, which was towards science and mechanics.”

This short sketch was written by his nephew.¹

Black has left a short autobiographical memorandum which runs as follows :—

“I was born at Bordeaux, 16th April, 1728. My father was a merchant settled there, but born in Ireland, and the son of a citizen of Belfast of Scotch extraction. My father’s residence at Bordeaux was in the suburb called the Chartron, and he had also a farm and country-house and vineyard on the other side of the river on a hill called Lormont, which commands a fine prospect of the river and city. At this villa, and at his house in town, he had sometimes the honour to receive a visit from the Baron de Montesquieu, who had the goodness to favour my father with his friendship and protection. My mother was of the family of Gordon of Halhead in Aberdeenshire,

¹ These notes were kindly shown me by Mrs. Black, widow of Colonel Black, the brother of the Rev. G. M. Black, a grand-nephew of the subject of this memoir.

a branch of which family had also settled in Bordeaux in the mercantile line.

“ I received the first beginning of education from my mother, who taught all her children to read English. At 12 years of age I was sent to Belfast, to live with some of my father's relations, and to acquire the rudiments of Latin and Greek. After 4 years spent there at a private school, I was sent to the University of Glasgow, where I attended all the lectures on the languages and philosophy in a regular succession. Being then required by my father to choose a profession or employment, I chose that of Medicine, the elements of which I began immediately to study by attending the lectures of the Professor of Anatomy and of Dr. Cullen, who was at that time Professor of Medicine at Glasgow. Dr. Cullen began also at this time to give lectures on Chemistry, which had never before been taught in the University of Glasgow, and finding that I might be useful to him in that undertaking, he employed me as his assistant in the laboratory, and treated me with the same confidence and friendship and direction in my studies, as if I had been one of his own children. In this situation, I lived three years.

“ In the early part of my chymical studies, the author whose works made the most agreeable impression on my mind was Markgraaf of Berlin ; he contrived and executed his experiments with so much chymical skill that they were uncommonly instructive and satisfactory ; and he described them with so much modesty and simplicity, avoiding entirely the parade of erudition and self-importance, with which many other authors en-

cumber their works, that I was quite charmed with Markgraaf, and said to Dr. Cullen I would rather be the author of Markgraaf's Essays than of all the Chymical works in the library. The celebrated Reaumur's method of writing appeared to me also uncommonly pleasing. After 3 years spent with Dr. Cullen, I came to Edinburgh to finish my education in medicine. Here I attended the lectures of Dr. Munro, senr. and the other medical Professors, until the summer of the year 1754, when I received the degree of Doctor of Medicine, and printed my inaugural Dissertation *De Humere Acido a Cibus Orto et Magnesia Alba.*"

Another fragment of autobiography was found by Dr. Robison, who succeeded Black as Lecturer on Chemistry in Glasgow in 1766. It was wrapped round a bundle of letters from President Montesquieu to Mr. Black, senior, at Bordeaux: "My father was honoured with President Montesquieu's friendship, on account of his good character and his virtues. He had no ambition to be very rich, but was cheerful and contented, benevolent and liberal minded, industrious and prudent in business, of the strictest probity and honour, very temperate and regular in his manner of life. He and my mother, who was equally domestic, educated thirteen of their children, eight sons and five daughters, who all grew up to be men and women, and settled in different places. My mother taught her children to read English, there being no school for that purpose at Bordeaux."

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Dr. Robison, who succeeded Black as lecturer in Chemistry in Glasgow in 1766, was asked by Black's

executors to revise and publish his lectures ; this he did in 1803 ; and to the book he prefixed a short life of Black. There is no correspondence dealing with his early days ; but Robison says that he spent his time, after his arrival in Glasgow in 1746, to good purpose. Letters from Black's father, which Robison had seen, "express his great satisfaction with the accounts which he had received from others of his progress in his studies." He attended George Ross's classes in "Humanity," and James Moore's in Greek ; John Loudon was Professor of Logic and Rhetoric ; he was succeeded in 1751 by the celebrated Adam Smith. Thomas Craigie was then Professor of Moral Philosophy ; and in 1752 Adam Smith exchanged his Chair of Logic for that of Philosophy, and retained it until 1764, to be himself succeeded by Dr. Thomas Reid, author of a well-known treatise on his subject. Natural Philosophy was taught by Robert Dick the elder ; in 1751 he was replaced by Robert Dick, M.D., his son. The Professor of Mathematics was Robert Simson, also M.D. ; he had been appointed to the Chair in 1711. These were the Professors of Arts.

In those days it was not customary for the average student to take the degree of Master of Arts ; it was as a rule only theologians who graduated in Arts. Even in the middle of last century, from the years 1861 to 1873, of 3122 students who entered in the Arts Faculty only 372 took a degree. The larger number attended classes to acquire knowledge.

The entry of Joseph Black as a matriculated student stands thus recorded in the College Album : " JOSEPHUS

BLACK filius natu quartus Johannis Black Mercatoris in Urbe Bourdeaux in Gallia, ex urbe de Belfast in Hibernia. Die Veneris Nov^{ris} 14^{to} A.D. 1746." At that time there was no examination for matriculation; indeed, matriculation was not necessary, unless the student wished to proceed to a degree, or unless he desired a vote at the quadrennial Rectorial election. The order of study was: first year, Latin; second year, Greek; third year, Logic; fourth year, Ethics; fifth year, Physics. The classes in Mathematics were not necessarily attended in the first session; if they were, the name was inserted under "Latin"; if in the second year, under "Greek," and so on. Black's name occurs as one of the "Nomina Discipulorum Classis Ethicae qui hoc anno Academiam Intrarunt sub Praesidio Magistri Thomae Craigie Professoris designati"; Craigie was Professor of Ethics; but it is not likely that Black, who in 1746 was eighteen years old, began his course of study with that subject. As he says himself, he had acquired the rudiments of Latin and Greek at Belfast, between the ages of twelve and eighteen, and he doubtless continued the study of the "Humanities."

Boys were precocious in these days. I remember on the occasion of a dinner at the Glasgow University Club being privileged to hear the views of Lord Kelvin, also a Belfast boy, and also a student of Glasgow College, on Education. He entered the University at the age of 10; and one must suppose that his remarks were a record of his personal experience. "Every boy," he said, "should be able by the age of 12 to write his own language with accuracy and some elegance; he should have a reading

knowledge of French, and be able to translate Latin and easy Greek authors, and have some acquaintance with German." Having learned thus the meaning of words," continued Lord Kelvin, "a boy should study Logic, so as to be able to apply his words sensibly."

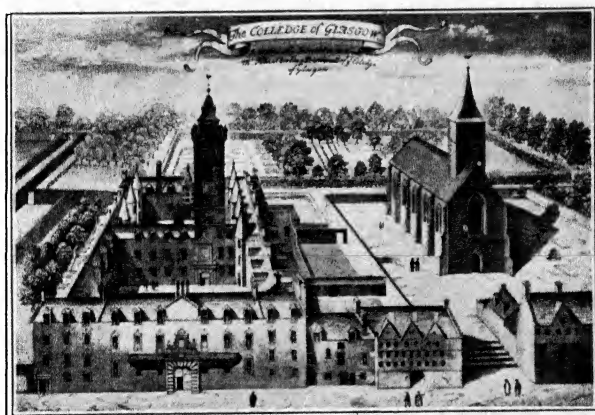
It is probable, however, that Black, although he entered the University under the presidency of "Master Thomas Craigie," did not attend his classes. From what his biographer Robison says, it might appear that Black had attended the lectures both of Dr. Hutchison, Professor Craigie's predecessor, as well as of Adam Smith, his successor in 1752; but this is impossible; in 1750 Black went to Edinburgh. And indeed he himself remarks that he attended "all the lectures in the languages and on philosophy in a regular succession."

Glasgow University at that time, and indeed until 1870, was situated in the High Street, a long, narrow street, winding slowly uphill from the Tron, or weighing-place, to the Cathedral. Many of the houses had their gables towards the street, and some were entered by outside stairs. Probably it was about the time of Black's attendance at the College (as the University was always termed) that a by-law was passed prohibiting the residents from keeping pigs in the triangular space between the house and the front stair, which, unlike ordinary stairs, did not stand at right-angles to the house, but parallel to it. The houses were small and irregularly built; in Black's day they were doubtless inhabited by a respectable set of citizens; but in the early part of last century many of them had become slums; and the "wynds" or narrow

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GLASGOW COLLEGE.

(ABOUT 1700).

lanes leading away from the street and entered usually through " closes," or narrow entries, were in the writer's recollection very unsavoury.

About two-thirds of the distance between the Tron and the Cathedral, on the right-hand side of the street, stood the " Old College." It was a sombre building—the sandstone of Glasgow, though excellent for building purposes, soon turns black—extending perhaps about sixty or eighty yards along the street. Above the entrance was a bust of Charles I. The Senate Hall occupied the front of the building. The story is told that during one of the official feasts held in that chamber, when it was the custom to sit long over the wine, one of the guests was struck with the pale face of his neighbour, who appeared to be asleep—no extraordinary circumstance. " What ails Drumsheugh ? " he asked the man beside him ; " he's looking gey gash." " 'Sh, man," said he, " he's been wi' his Maker thae twa hours."

A stair led up to the Senate-room, flanked by a heraldic lion and unicorn. Opposite the main entrance, at the other side of the court, stood a tower ; and in a niche in the wall stood a bust of Zachary Boyd, the author of a rimed version of parts of the Bible. Passing through the archway under the tower, one entered the College Green, a meadow stretching down towards a brook, named the Molendinar, on which mills used to stand. Immediately alongside of the College were the Professors' houses, thirteen in number ; the incumbents of the older chairs had each a house, facing a courtyard, with an entrance from the High Street. On the other side of the

College stood the College church, in which sermons were preached every Sunday by one of the Professors of the Theological Faculty. The major portion of this building had been erected in 1632; a library was also added. The noblemen and gentry of the district all subscribed to help the cause of learning; and the King, Charles I himself, headed the list of subscriptions; the letter which he directed to be written bears the sign-manual, and runs as follows:—

“ Charles R.

“ It is our gracious pleasure to grant for advancement of the librarie and fabrick of the Colledge of Glasgow the soume of Two Hundred Pounds Sterlin.”

The note follows in a different hand: “ Y^e soume was payd by y^e Lord Protector An. 1654.”

This was the scene of Black's labours. Early rising was in fashion; in the writer's time the lectures began at eight in the morning; in Black's at seven. The doors were closed punctually at four minutes past the hour; and the inhabitants of Albion Street, which faced the entrance to the College, were in the habit of seeing numbers of youths in scarlet flannel gowns scurrying towards the gate, with the certainty of being locked out the moment the tinkling bell had ceased to ring. In the Humanity and Greek classes the hour was opened with a short prayer; then the “ roll ” was called; each answered in turn “ adsum ” when the Latin equivalents of the Christian names were given, beginning with “ Adamus.” Some were quaint; it took long before we recognised that “ Kentigernus ” stood for the somewhat

uncommon name of the Glasgow Saint Mungo, sometimes adopted as a prænomen by loyal citizens ; nor was " Milcolumbus " easily recognised as Malcolm.

Lads in the junior class of " Humanity " were supposed to have already some knowledge of the language ; it was begun at school at the age of 7 or 8, and the boys at College were as a rule 14 or 15 years old. There was always, however, a considerable sprinkling of seniors ; generally men destined for the ministry, whose means had not permitted an earlier start. Some of these came from the Highlands and Islands, and had very small acquaintance with the English language. I remember, in the senior " Humanity " class, sitting next a lad from Fort William, whose native language was English, although he spoke Gaelic fluently ; on my other side was a man about thirty from Benbecula, an outlying island south of Harris, in the Hebrides. The latter had great difficulty in understanding the English equivalents of some of the words of Horace's odes ; and he frequently held conversations in Gaelic with my right-hand neighbour in order to get at the meaning of some difficult passage. The order of proceedings both in the Latin and the Greek classes was : the Professor called out the name of one of the students and asked him to translate a given passage ; if he did it correctly he was asked questions as to the syntax and as to the meaning of the passage ; if he failed to answer, the question was put " round the class." In this manner ten or twelve students were examined daily. In Black's day the English language was used only in case of necessity ; as a rule, the students

were addressed in Latin. It used to be related that, the door having been left open, a student, incommode by the draught, ejaculated, "Claude ostium!" whereupon the Professor, annoyed at the interruption, shouted, "Claude os tuum!"

The method of teaching in the classes of Logic and Rhetoric, and of Moral Philosophy was different. In these classes the Professor "read" lectures. The students took notes in a scrap-book, and wrote them out in a fair hand each evening. Usually they collated them with those of their class-fellows; and, indeed, it was possible to buy the notes thus accumulated. There was very little variation from year to year. Robison, in his preface to his edition of Black's lectures, states that he utilised Black's own notes for the most part; but as these were in places fragmentary and difficult to decipher, "I had the assistance of a very fair copy of notes, taken by a student, or rather manufactured by a comparison of many such notes. Copies of this kind were to be purchased for four or five guineas. This copy belonged to Dr. Black, and he had made many alterations and insertions of whole pages with his own hand." I myself possess a copy of manuscript notes of "Lectures read in Edinburgh by Joseph Black, M.D., in 1773." It is well bound, and written by an unknown scribe in an excellent hand.

The work of classes in Logic and Philosophy, besides such lectures and the reading of books recommended by the Professors, consisted in writing periodical essays on some prescribed subjects. Black appears to have followed such courses of instruction for four years, that is till May,

lasted from the 1st November till the close of the session, and the "Prize-giving." The prizes were determined, according to old custom, by the votes of the class, and, on the whole, it was a just plan. Some of us may have thought that the order of prize-takers, say from the eighth prize on, might have been improved; but voting was regarded by the students as a serious responsibility, to be exercised with discretion.

In Black's time, William Graham, Duke of Montrose, was Chancellor; indeed, the Dukes of Montrose filled that office from 1715 to 1837; before them the Chancellors were the Archbishops of Glasgow. The Rector was at that time Sir John Maxwell, Bart.; he was elected by the suffrages of the students, divided for the purpose into "nations," of which there were four; the "Glot-tiana," belonging to the County of Lanark; the "Transforthiana," a name which explains itself; the "Rothseiana," from the Counties of Bute, Renfrew, and Ayr; and the "Loudoniana," comprising all other students. The contest is generally run on political lines; but history does not record on which side Black voted.

Having completed his Arts course of study, Mr. Black, Joseph's father, naturally required his son to make choice of a profession; he elected that of Medicine. Medicine, in those days, was the only entry to Science. On looking over the old lists of teachers in the University one is struck with this. Among Doctors of Medicine were Robert Dick, who held the chair of Natural Philosophy from 1751-7; Robert Sinclair and Robert Simson,

Professors of Mathematics from 1616, be related to the occupants of the chair of Chemistry from 1747 to 1874, with the single exception of Black's immediate successor, John Robison, LL.D. Black's leanings towards natural science, however, were probably encouraged by his intimate friendship with the son of the Professor of Natural Philosophy, Dr. Robert Dick, later successor to his father in the chair, who, unfortunately, occupied it only a few years, for he was early cut off by death. Black also owed much to Cullen, of whom a very interesting account is given by Thomas Thomson in his *History*. Cullen was Lecturer in Chemistry in the University from 1746 to 1756; and in 1751 he was appointed Professor of Medicine; at that time, and, indeed, until Thomas Thomson taught chemistry, that subject was taught only by a lecturer. Thomson attributes to him a singular talent for arrangement, distinctness of enunciation, vivacity of manner, and profound knowledge of his science—in short, enthusiasm—qualities which made him adored by his students. He took especial pains to gain their friendship by frequent social intercourse with them, and no doubt early recognised Black's great promise. Robison says that Cullen saw in chemistry not merely a curious and useful art, but a “vast department of the science of nature, which must be founded on principles as immutable as the laws of mechanism, and which may be one day formed into a great system of doctrines, of various degrees of subordination and dependence. He was determined to attempt this mighty task, and promised himself great reputation by its accomplishment. Nor

was he altogether disappointed. He quickly succeeded in taking chemistry out of the hands of the artists, the metallurgists, and the pharmaceutists, and exhibited it as a liberal science, the study of a gentleman. His pupils became zealous chemists as well as refined physiologists. Young Black was particularly delighted with a view which accorded so happily with those enlarged habits of thought which he had acquired ; and his great bias to this study was soon perceived by Dr. Cullen. No professor took a more lively interest in the progress of an emulous student than Dr. Cullen. It was his delight to encourage and assist their efforts, and therefore he was not long in attaching Mr. Black to himself, in the most intimate co-operation ; insomuch that the latter was considered as his assistant in all his operations ; and his experiments were frequently adduced in the lecture, as good authority. Thus began a mutual confidence and friendship, which did honour both to the Professor and his pupil, and was always mentioned by the latter with gratitude and respect."

Cullen's single contribution to chemico-physical literature dealt with the boiling of ether on the reduction of pressure, and its growing cold during the process. The reason of this behaviour, however, was later discovered by Black, for Cullen confined himself to recording the observation.

In his autobiographical sketch Black says that he spent three years with Cullen ; he probably began to attend Cullen's lectures in November, 1749, the last year of his studies in Arts.

CHAPTER II

CHEMISTRY, in these days, was handmaid to medicine; the influence of the iatro-chemists, founded by Paracelsus, still held its sway, although certain bold investigators—among them Boyle, Mayow, and Hales—a century before, had shaken themselves free from its thralldom. And the lectureship on chemistry in Glasgow was regarded as a step to a more remunerative position, and was held, along with the Crown professorship of medicine, by Cullen from 1751 to 1756.

Black's methodical habits led him to keep a sort of commonplace book, in which not merely the results of his experimental work were entered, but also notes on medicine, jurisprudence, or matters of taste; and he practised "double entry," for he also kept separate journals in which these notes were distributed according to their subjects. From these notebooks the dates of his most important discoveries can be traced.

Dr. Robison, who had access to these notes, found in the oldest parcel queries respecting the nature of cooling mixtures, and the cold produced by liquefaction; but it was not until his removal to Edinburgh, in the year 1752, that any observations on the nature of fixed air occur. Robison wrote: "I do not imagine that Mr. Black's researches at this time (or perhaps at any time)

have been keen or pertinacious. This could not accord with the native gentleness of his mind ; but his conceptions being distinct, and his judgment sound, his progress in scientific research, if slow, was steady, and his acquisitions were solid. Perhaps this moderation and sobriety of thought was his happiest disposition, and the most conducive to his improvement."

In 1751 Black went to Edinburgh to finish his medical studies, and lived with his first cousin, Mr. James Russell, Professor of Natural Philosophy there, whose mother, a Miss Gordon, was sister to Black's mother. There he took the degree of doctor of medicine in 1754. It is true that he might have graduated in Glasgow three years earlier ; but no doubt his thoroughness made him wish to offer a thesis worthy of praise, and it was this thesis which established his reputation. More of this hereafter.

It is at this date that the first of his preserved letters was written ; it was to his father. According to the custom of the time he begins :—

" Most Honrd Sir

" Your most affectionate letter of the 8th Aprill shews you in such a light as must warm the heart of a son with the highest degree of gratitude and affection. Others in the pursuits after happiness or pleasure must commonly seek those sources of it which they cannot enjoy without some inconvenience to the rest of their fellow creatures ; hence they have their imaginary happiness so much soured by Envy, Jealousy, or self-

disapprobation that they find themselves dissappointed. Your happiness on the contrary is quite secure because you place it entirely in making others happy and doing those things to the utmost of your power which you can afterwards reflect upon with satisfaction. I must own your letter had that effect upon me that it made me apply to my work with double eagerness and alacrity with the hopes of being some time what you are at present.

“ I am not yet installed into the order of the great wig, but have gone through all the examinations, & nothing is wanting but the ceremony, & that has been put off by the Professors to wait for some others that are to be promoted along with me 6 days hence.

“ In my last letter to you I proposed to go immediately to London to spend some time in the Hospitals there. I am now advised to put that off and remain here yet a while longer ; & I must own the reasons for it are very strong & quite unanswerable by me unless you disapprove of them. The following are the chief of them. I have now studied the Theory of medicine & have likewise been taught every thing upon the Practice which can be learned in a College. I have also seen some real Practice & have even practised a little myself. But all this is not enough. I should be thoroughly acquainted with the real Practice & this is a thing very different from what can be learned in a College ; thus for instance we are taught by our Professors that if a sick person breaths with great difficulty, one thing must be done ; if his respiration is yet more laborious, another. But how shall we judge of the nice degrees of laborious breathing unless

from a dayly & familiar acquaintance with, & study of, the appearances and looks of Patients &c. Most young Physicians neglect this essential point of their art in their education & very often acquire it when they come to Practice at the expense of their patients' safety. I have not had time this last winter to apply to it sufficiently ; tho I had the opportunities, my attention was too much taken up with some of the Colleges, preparing my Thesis, & recalling to my mind everything I had learned, on account of the examinations. If I go to London to acquire this part of medicine, I may see a good deal of Practice, but I am a stranger there, & have no acquaintance whom I can venture to trust so much or be so familiar with as to trouble him with all my questions and doubts.—On the contrary here, medicine is allowed on all hands to be in a very flourishing condition. It is practised in the most rational & simple manner. I have the happiness to be lodged with a Gentleman who is justly esteemed by all his Brethren, who has extensive practice both as a Physician & Surgeon & tho no Doctor himself, yet the oldest of them are not ashamed to consult with him in private. Besides this he is my intimate & familiar Friend & is willing upon every occasion to teach me as far as he knows himself.

“ When I am well instructed in a method of Practice here, a very short time of London will be sufficient ; for then I need only observe the different manner of doing the same thing there, which I shall soon be master of.

“ These, sir, are the chief of the reasons which have been urged to me for staying here some time longer &

which I thought so good that I determined to acquaint you with them & in the meanwhile will employ my time to the best advantage till I have your opinion of them

“ I am D^r Sir Your most affect^e & Dutyfull Son,

“ Edinb^g 1st June 1754.”

“ JOSEPH BLACK.

This appears a suitable place to give an account of Black's celebrated thesis, which gained for him not merely the degree of Doctor of Medicine, but also brought his name before every “ philosopher ” in Europe and America as that of a man who had made a discovery of more fundamental influence on the progress of Chemistry than any which had previously been described.

Besides having been published as his thesis for the Doctorate, this paper was communicated to the Philosophical Society of Edinburgh in June, 1755, and appeared in the second volume of their essays in the following year.

In the olden days it was considered quite as marvellous that a gas could be made to occupy a small volume, or that “ air ” could be produced in quantity from a stone, as that an Arabian “ djinn ” of enormous size and ferocious mien could issue from a bottle, as related in the “ Tale of a Fisherman,” one of the charming stories of the *Arabian Nights' Entertainments*. It is true that in the middle of the seventeenth century Robert Boyle had enunciated his famous discovery, “ Touching the Spring of the Air ” ; in which he proved that the greater the pressure to which a gas is exposed the smaller the volume it will occupy. But however great the pressure, Boyle's

air remained air. It might have been thought that the boiling of water into steam should have convinced men that a liquid, at least, could be changed into a gas ; but the fact that steam changed back to water probably prevented attention being paid to its comparatively large volume while hot. It was Black's discovery of the production of carbonic-acid gas, or, as he named it, "fixed air," from marble, which first directed notice to this possibility of the production of a gas from a solid ; and, further, the peculiar property of this gas—its power of being fixed—was one which completely differentiated it from ordinary air. Stephen Hales, the botanist, it is true, had distilled many substances of vegetable, animal, and mineral origin ; among them he treated many which must have produced impure hydrogen, marsh-gas, carbonic-acid gas, and oxygen ; but Hales contented himself with measuring the volume of gases obtained from a known weight of material, without concerning himself as to their properties. And, as the result of many experiments, he concluded that "our atmosphere is a *chaos*, consisting not only of elastick, but also of unelastick air-particles, which in plenty float in it, as well as the sulphureous, saline, watry, and earthy particles, which are no ways capable of being thrown off into a permanently elastick state, like those particles which constitute true permanent air." This was the current belief as regards the nature of air.

The cause which gave rise to Black's famous research is a curious one. Sir Robert Walpole, as well as his brother Horace, afterwards Lord Walpole, was troubled

with the stone. They imagined that they had received benefit from a medicine invented by a Mrs. Joanna Stephens; and through their influence she received five thousand pounds for revealing the secret, which was published in the *London Gazette* on the 19th June, 1739. It was described as follows:—

“ My medicines are a Powder, a Decoction, and Pills. The powder consists of Egg-shells¹ and Snails,² both calcined. The decoction is made by boiling some Herbs³ (together with a Ball, which consists of Soap,⁴ Swines'-Cresses, burnt to a Blackness, and Honey) in water. The Pills consist of Snails calcined, Wild Carrot seeds, Burdock seeds, Ashen Keys, Hips and Hawes, all burnt to a Blackness, Soap and Honey.”

Dr. Cullen and his colleagues held opposing views as to the efficacy of such quaint and caustic remedies; and it was with the object of discovering a “ milder alkali,” and bringing it into the service of medicine, that Black began his experiments on magnesia. They are described in a paper entitled “ Experiments upon Magnesia Alba, Quicklime, and some other Alcaline Substances ”; it

¹ Egg-shells and Snails calcined in crucible surrounded with coal for 8 hours. Then left in earthenware pan to slake in a dry room for 2 months. The Shells thus become of a milder taste, and fall into powder.

² Snails left in crucible until they have done smoaking, then rubbed up in a mortar. Take 6 parts of Egg-shell to 1 of Snail-powder. Snails ought only to be prepared in *May*, June, July and August.

³ Herbs of decoction: Green Chamomile, Sweet Fennel, Parsley and Burdock; leaves or roots.

⁴ Soap: Best Alicant Soap.

was the chemical contents of his thesis for the degree of M.D., which he took at Edinburgh in 1754; he had been making the experiments since 1752. The actual thesis was in Latin: "De Humore Acido a Cibis orto, et Magnesia Alba"; the pamphlet was published in the following year.

The medicines in vogue as solvents of the urinary calculus were all caustic; the *Lapis infernalis*, or caustic potash, and the ley of the soap-boilers, or caustic soda. These substances are made from mild alkali, or carbonates, by boiling their solutions with slaked lime, itself produced by slaking quicklime with water. Now quicklime is formed by heating limestone in the fire; it thereby acquires its burning properties, or causticity; and this it was supposed to derive from the fire, of which it absorbed, as it were, the essence. The act of boiling the mild alkalies with lime was supposed to result in a transference of this educt of fire to the alkalies, which themselves became caustic. Lime-water, or a solution of caustic lime, was used as a solvent for the calculus; and it was an attempt to produce a less caustic solvent from Epsom salts that induced Black to begin his researches.

As his notes show, Black began by holding the old view. He attempted to catch the igneous matter as it escaped from lime, as it becomes "mild" on exposure to the air: he appears to have made some experiment with this view; but his comment was: "Nothing escapes—the cup rises considerably by absorbing air." Two pages further on in his notebook he records an experiment to compare the loss of weight sustained by an ounce of chalk

when it is calcined with its loss when dissolved in "spirit of salt," or hydrochloric acid; and he then evidently began to suspect the reason of "mildness" and "causticity."

Another memorandum, a few pages later, shows that he had solved the mystery. "When I precipitate lime by a common alkali there is no effervescence. The air quits the alkali for the lime, but it is not lime any longer, but c.c.c. It now effervesces, which good lime will not."

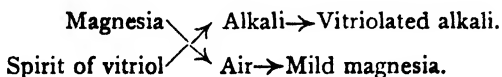
But we must trace the chain of reasoning which led him to come to this conclusion.

Having prepared "mild" magnesia by mixing Epsom salt or sulphate of magnesia with carbonate of potash, or "pearl-ashes," he found that it is "quickly dissolved with violent effervescence or explosion of air by the acids of vitriol, nitre, and of common salt, and by distilled vinegar"; that the properties of these salts—the sulphate, nitrate, chloride, and acetate of magnesium—differ greatly from those of the common alkaline earths; that when boiled with "salt-ammoniac," or chloride of ammonium, volatile crystals of smelling-salts were deposited on the neck of the retort, which, on mixing with the chloride of magnesium remaining in the retort, reproduced the "mild" magnesia; that a similar effect is produced by boiling "mild" magnesia with "any calcareous substance"; while the acid quits the calcareous salt to unite with the magnesia, "mild" magnesia is again precipitated on addition of a dissolved alkali.

On igniting "mild" magnesia, it changed into a white

powder, which dissolved in acids without effervescence. And the process of ignition had deprived it of seven-twelfths of its weight. Black next turned his attention to the volatile part; he attempted to restore it by dissolving the magnesia in a sufficient quantity of "spirit of vitriol" or dilute sulphuric acid, and separated it again by the addition of alkali. The resulting white powder now effervesced violently with acids, and "recovered all those properties which it had lost by calcination. It had acquired besides an addition of weight nearly equal to what had been lost in the fire; and as it is found to effervesce with acids, part of the addition must certainly be air."

Black here made an enormous stride; he had weighed a gas in combination. He argues further: "It seems therefore evident that the air was forced from the alkali by the acid, and lodged itself in the magnesia." We may represent the change diagrammatically thus:



The next step was to try whether mild magnesia lost the same weight on being mixed with acid as it did when heated in the fire. But, owing probably to the solubility of the fixed air in the water, a much less loss was found on dissolving the magnesia (35 grains out of 120) than by heating it (78 grains out of 120). The amount of acid required to expel the fixed air was, however, practically the same as that required

to dissolve the *magnesia usta*, or heated magnesia (267 and 262 grains).

Turning his attention next to chalk, he dissolved some in muriatic acid, and having precipitated with fixed alkali no difference could be detected between the recovered and the original chalk. He had thus first separated the fixed air from the chalk, and then recombined the two. These experiments led Black to conclude that fixed air must be of the nature of an acid, for it converts quicklime—the acrid earth, as he termed it—into crude lime, or mild earth, the mildness being due to its union with fixed air.

The explanation is thus given of the curious fact that, mild magnesia, mixed with lime-water, gives pure water ; for the fixed air leaves the magnesia and unites itself to the lime, and both the *magnesia usta* and the chalk which are formed are insoluble in water. And the action of quicklime in causticising alkali is similarly explained by its removing the fixed air from the alkali, thus rendering the latter caustic, while itself becoming mild.

Reasoning further, Black foresaw that caustic alkali, added to Epsom salt or vitriolated magnesia, should give a precipitate of magnesia which should not effervesce with acids, for here fixed air is excluded ; and, also, that caustic alkali should separate from acids lime in the quick state, only united with water.

Similar experiments of treating chalk with acids and heating it, which had been performed with magnesia, showed similar results.

But it had yet to be demonstrated that fixed air did

not share the properties of ordinary atmospheric air. So Black placed four fluid ounces of lime-water, as well as four ounces of common water, under the receiver of an air-pump, and exhausted the air ; air rose from each in about the same quantity ; it therefore appeared that the air which quicklime attracts is of a different kind from that which is mixed with water. Quicklime does not attract air when in its most ordinary form, but is capable of being joined to one particular species only, " which is dispersed through the atmosphere, either in the state of a very subtle powder, or, more probably, in that of an elastic fluid. To this I have given the name of *fixed air*, and perhaps very improperly ; but I thought it better to use a word already familiar in philosophy than to invent a new name, before we be more fully acquainted with the nature and properties of this substance."

The next step was to examine the nature of caustic alkali, and to prove whether it gained weight on being made " mild." This was achieved indirectly, by finding the amount of acid required to neutralise the same weight of caustic alkali and " salt of tartar "—what we know as potassium carbonate. Six measures of acid were required to saturate the former, and five the latter ; and Black was very near the truth ; indeed his error was only about 4 per cent. He proved, by addition of sulphuric acid, that the caustic alkali contained no lime, and therefore that its causticity was not due to an admixture of that substance.

To prove that limestone, or magnesia, " loses its air "

when dissolved in an acid, but regains it on addition of a mild alkali, the acid in which the lime was dissolved passing to the alkali, Black added caustic ley to a solution of Epsom salt, the result being a precipitate of magnesia ; this dissolved in vitriol without effervescence, showing that no fixed air had taken part in the change. He also, on adding caustic alkali to a solution of chalk in spirit of salt (or hydrochloric acid), produced lime, which on being dissolved in water produced lime-water, indistinguishable from that produced from quicklime and water. He goes on to say that " had we a method of separating the fixed alkali from an acid, without at the same time saturating it with ' air,' we should then obtain it in a caustic form." It can be done, it is true, by heating nitre with charcoal, but the alkali is then found saturated with air ; and again by heating the alkali salts of vegetable acids the same occurs. Black conjectures that the fixed air must be derived either from the nitre or the charcoal in the first case (indeed it is derived from both, the nitre supplying the oxygen to the carbon) ; and in the second, he remarks that the vegetable acid is not really separated, but rather destroyed by the fire. How nearly he came to the discovery that fixed air is produced from carbon !

It was Dr. Hales's experiments which put Black first on the track of " fixed air." After noting how magnesia (i.e. the carbonate) loses a great part of its weight on distillation, much more than that of the water which it contained, he says in his lectures : " This appeared at first an unaccountable fact ; but it made me recollect

some of Hales's experiments, described in the essay to which he gave the title of Analysis of the Air, and in other parts of his works." After giving a brief sketch of Hales's methods, he goes on : " As what had happened in the last experiment with magnesia appeared to be very similar, I began to suspect that the loss of weight which it suffered in the fire was occasioned, in the same manner, by the loss of a quantity of elastic aerial matter, or air, which had escaped. And this supposition appeared the more probable, as it was very consistent with one of the qualities of burnt magnesia ; I mean its uniting with acids without effervescence. For I began to suspect that the effervescence of the common magnesia proceeded from the air which it contains, and which is expelled by the superior attraction of the acid ; and that the reason why burnt magnesia did not effervesce was, that it did not contain this air, the air having been expelled from it by the action of heat." Further on, he states : " I therefore concluded, with respect to the other alkalies and alkaline earths, that their effervescence with acids depended on the same cause ; that they all contain a large quantity of fixed air, which is expelled when they unite with acids ; and that this air adheres to them with considerable force, since, notwithstanding that it is such a volatile substance, a full red heat is necessary to separate it from magnesia, and the same red heat is not necessary to expel it entirely from the alkalies, or to deprive them entirely of their power of effervescing with acid salts." " With respect to the calcareous earth in particular, I imagined that, when it

is exposed to the action of a strong fire, and thereby converted into quicklime, the change it suffers depends on the loss of a large quantity of fixed air which is combined with this earth in its natural state ; that this air is expelled by the heat ; and that the solubility in water, and the remarkable acrimony which we perceive in quicklime, do not proceed from any subtile or other matters received in the fire, but are essential properties of this earth, depending on an attraction for water, and for those several substances with which the lime is disposed to unite ; but that this attractive power or activity remains imperceptible, so long as the lime or calcareous earth is in its natural state, in which it is saturated and neutralised by the air combined with it."

These sentences give some idea of the clear method of statement followed in his lectures.

From 1754 to 1756 Black appears to have practised in Edinburgh. Whether he paid his projected visit to London is not known. But in 1756 Dr. Cullen exchanged his Chair of Medicine, which he had filled in Glasgow since 1751, and his lectureship on Chemistry, which he had held since 1747, for the Chair of Chemistry in Edinburgh ; and it was fortunate for Black that his thesis had been published in 1754, for by the time the Glasgow Professorship and Lectureship were vacant his work was beginning to meet with recognition. No doubt Cullen recommended his old pupil, who had so signally distinguished himself, as the most fitting occupant of the combined posts ; and in 1756 Black moved to Glasgow.

It is related by Joseph's brother that he sent several

copies of his thesis to his father in Bordeaux ; and the old gentleman showed one to the president Montesquieu. After a few days Mr. Black received a visit from the president, who said to him : “ Mr. Black, my very good friend, your son will be the honour of your name and of your family.” No letters, however, have been preserved relating to this period.

Black did not long retain the Anatomy Chair, but made an arrangement with the Professor of Medicine to exchange duties, with the concurrence of the University. Robison gives a short sketch of his work in the field of the “ Institutes of Medicine,” as the chair was entitled. “ They gave the greatest satisfaction by their perspicuity and simplicity, and by the cautious moderation of all his general doctrines. It required, however, all this perspicuity, and all this neatness in the manner of exhibiting simple truths, to create a relish for this great moderation and caution, after the brilliant prospects of systematic knowledge to which the students had been accustomed from the Doctor’s celebrated predecessor. But Dr. Black had no wish to form a medical school which should be distinguished by some all-comprehending doctrine. He contented himself with giving a clear and systematic account of as much of physiology as he thought founded on good principles, and a short sketch of such general doctrines as were maintained by eminent authors, but perhaps on a less firm foundation. Without this, he said that his students could not read their writings, which, in other respects, were highly valuable. He then endeavoured to adduce a few canons of medical practice ;

and concluded with certain rules founded on successful practice only, but not so deducible from the previously delivered principles of physiology; observing that we should not despair of being able, on some future day, to proceed in the opposite direction, deducing the first principles entirely from the practice. It does not appear, however, that he had ever satisfied himself with his method of treating these subjects. He did not encourage conversation on those topics; and there are no remains of his medical lectures to be found among his papers. I owe the account now given of them to a respectable surgeon in Glasgow, who attended these lectures in the two last years of his Professorship in that University."

Black engaged in practice while he held his double chair in Glasgow. It cannot therefore be wondered at that he found little time for research. Indeed, Robison writes that he was never free from anxiety about his patients, being deeply impressed with the immense importance of the healing art. Moreover, he doubtless considered that he had resolved the problem which he had set himself.

In a letter to his father, dated 4th April, 1757, Black tells of his appointment to the Chair of Medicine: "I have little to say with regard to myself but that the long expected commission promoting me to the Professorship of Medicine is at last come down; that having found my health somewhat impaired by the more than ordinary application I have been obliged to give of late, I am under a necessity of being more attentive to it than usual, but I now find myself in a better way, and hope

to regain the whole of my strength in summer. I think I remember in your possession some actual curiosities which were picked out of a lime quarry on Blamont Hill, & consisted of petrified shells, some of them incrustated with crystals of spar. As it is a part of my business to mention and exhibit such Phænomena of Nature, any specimens of this kind would be extremely acceptable to me.

“ I am, Dearest Sir,

“ Your most Dutifull & most affe^{te} son

“ JOSEPH BLACK.”

“ Glasgow, 4th April, 1757.”

Robison says that Black's countenance at that time of life—he was then about twenty-eight—was equally engaging as his manners were attractive, and in the general popularity of his character he was in particular a favourite with the ladies. No one, so far as we know, was singled out by his preference ; and to the end of his days he remained unmarried. It appears that the ladies regarded themselves as honoured by his attentions, and we are told that these attentions were not indiscriminately bestowed, but exclusively on those who evinced a superiority in mental accomplishments or propriety of demeanour, and in grace and elegance of manners.

Another letter to his father is as follows :—

“ DEAREST SIR,

“ I have 2 kind letters of yours by me unanswered, which the constant hurry of my business this winter

& the necessity I was under of taking as much relaxation & exercise as possible on account of my health, have made me neglect but too long. I have therefore taken the first day of the vacation to answer them. The kind expressions of affection & fond regard which you give me in all of your letters make me extremely happy & excite the most lively sentiments of love & gratitude.

“ You need not imagine my dear sir that there is any need of your enumerating the many demands for money which lay you under a necessity to be as saving of the family stock as possible—I am fully sensible that it cannot be better placed than in your hands who employ your attention chiefly to the care & protection of your numerous family & are ready to help wherever the danger of distress demands your assistance. I am fully sensible too that I have already been very expensive & one of my most agreeable reflections on my present situation is that I shall not now anyhow be a burthen to you. . . . As for myself I have supported the toil of last winter much better than expected—this I attribute entirely to frequent riding which I had recourse to whenever I found myself oppressed & lowspirited & I am so fully convinced of its being a specific for frailty of the body & langour of the mind that I believe I shall purchase a horse this summer although he should put me a little to my shift to maintain him.

“ I am my dear Sir with sincere gratitude & love your

“ dutiful & affect^{te} son

“ JOSEPH BLACK.”

“ Glasgow, 16 May, 1758.”

A fourth letter from Black to his father has been preserved ; it is written from Glasgow, and shows how his time was occupied :—

“ DEAREST SIR,

“ I cannot reflect without blushing upon the long time I have been in your debt for many of the kindest and most agreeable letters that ever son received from a father, & yet I hope it is not from want of sensibility to your goodness that I have been so long without acknowledging it. My business as a member of the College, & the moderate share of Practice I have in town & country, tho they would be very little trouble to others who have more spirits and activity, is yet enough to give me constantly some care and employment, & seldom leaves me in that state of ease & good humour in which one would wish to write to their friends. I no doubt could write much oftener but I cannot always do it chearfully, & I think in that case it is better to let it alone. It gives me great uneasiness to read the account you give of the insolent & brutal behaviour with which you were treated by that riotous mob. There is no assembly so deaf to reason, & so insensible to generosity and justice as one of that kind. But if what I hear be true, they had some cause of complaint & ill humour against the country gentlemen. I am told that some of these last had not only obliged their tenants to do the duty upon the high roads which the Law requires, but under that pretence had made them lead gravel &c, for their private avenues and the walks of their gardens.

No doubt the tenants might have had redress in a much better & more effectual manner, but if I remember the manners of Ireland right, there is rather too much partiality upon all occasions for a gentleman when compared with a common man.

“ I perceive by your last that you had got from brother Robert an account of his journey hither, & of the agreeable time we spent together when he was in this country. When we parted at Edinb. Jamie Burnet & I came west by Falkirk, saw the works in the neighbourhood of that town, lately set on foot by a brother Doctor & chemist, for manufacturing iron from the ore in a very large & extensive way, called upon Katy Burnet on our way to Glasgow, brought her to town with us, & next day he set out for Aberdeen again, & she returned to the country where she continues to be extreamly diligent & to make good progress.

“ The frequent bleak weather we have had this summer has made me more subject to colds than the last ; but these have been as ordinary chiefly in my head & do not distress me in any other way than in making me a little stupid & dispirited. I resolved last Spring to have lived this summer a month or so in the country, but have not got it effected.

“ I have at last wrote a paper upon the use of lime in bleaching which I transmitted some posts ago to Mr. Ferguson, & shall do anything further that is in my power. I see at the foot of your letter to James Burnet you mention a memorial from the Linnen Manufacturers which at their desire you had sent me. I received the

letter you enclosed to me from Mr. Ferguson in April last, but have not seen anything else upon the subject ; this I take notice of only to ask if you transmitted any other memorial. You likewise mention a considerable grateful reward promised by the Commissioners of the Linnen Board ; I should be glad 'entre nous' to know the particulars of this for I never heard of any reward before, nor ever expected it. I am Dearest Sir, with the sincerest wishes for the long continuance of your health & chearfullness

“ Your much obliged & affectionate son

“ JOSEPH BLACK.

“ Glasgow, 20th Sept^r, 1763.”

The rough draft of this letter is also extant ; it is curious to think of the care with which correspondence was conducted by Black.

These letters to his father, in their respect and affection, expressed in a manner somewhat amusing to modern readers, show how close a bond united father and son. The father is evidently proud of the position gained by his talented son, and Black is grateful for the help and sympathy which he received from home.

CHAPTER III

THE volumes kindly lent me by Mrs. Black contain all the correspondence to and from Black which has been preserved. It is of a very varied character, and much of it is of no particular interest. As already remarked, Black was the most methodical of men ; he docketed all his letters, and, if space allowed, he drafted his reply on the back of the letter received ; if not, he used the blank sheets of letters of invitation, or accounts, in noting his answers. He wrote a beautifully distinct hand ; his sentences are well punctuated ; and his spelling is modern, except in certain words, such as " tried," " extreamly," and a few others ; he invariably omits the " gh " in " through," " though," and similar words, thus anticipating one of the efforts of spelling reformers.

It was in Glasgow that he carried out his second great piece of work, dealing with the Latent Heats of liquids and vapours ; and it appears appropriate to give some account of it in this place.

It has already been mentioned that Black's teacher, Dr. Cullen, had noticed that when ordinary ether, a very volatile liquid of low boiling-point, is placed under the receiver of an air-pump, it begins to boil ; and that its boiling has the curious effect of cooling it. An account of this experiment was published in the year 1748, and is

to be found in *The Edinburgh Physical and Literary Essays*. Robison, who looked through Black's early notes, says: "In the oldest parcels of these notes, I find queries respecting the nature of cooling mixtures, and the cold produced by liquefaction; but it is not till some time after, I think not before the year 1752, that I can date any observation relative to fixed air." It is probable that Black's attention was first directed to the subject of latent heat by conversation with Cullen. His published lectures begin with the heading—"General Effects of Heat"; and the subdivisions of the subject are: "1st. To ascertain what I mean by the word HEAT in these lectures. 2ndly. To explain the meaning of the term cold, and ascertain the real difference between cold and heat. 3rdly. To mention some of the attempts which have been made to discover the nature of heat, or to form an idea of what may be the immediate cause of it. 4th, and lastly, I shall begin to describe the sensible effects produced by heat on the bodies to which it is communicated."

He begins by arguing that it is heat which is the positive thing, and not cold, which is merely absence of heat. He goes on to say: "But our knowledge of heat is not brought to that state of perfection that might enable us to propose with confidence a theory of heat, or assign an immediate cause for it"; and further: "When we have at last attained it, I presume that the discovery will not be chemical, but mechanical." He then touches on Lord Verulam's (Bacon's) surmise, that in as much as heat can be generated by percussion, or by friction, it

must consist in a motion of the particles of bodies ; but he inclines rather to a suggestion of Cleghorn, that " heat depends on the abundance of that subtile fluid, elastic matter, which had been imagined before by other philosophers to be present in every part of the universe, and to be the cause of heat. But these philosophers had assumed, or supposed one property only belonging to this subtile matter, viz. its great elasticity, or the strong repellency of its particles for one another ; whereas, Dr. Cleghorn supposed it possessed another property also, that is, a strong attraction for the particles of the other kinds of matter in nature, which have in general more or less attraction for one another. He supposes that the common grosser kinds of matter consist of attracting particles, or particles which have a strong attraction for one another, and for the matter of heat ; while the subtile elastic matter of heat is self-repelling matter, the particles of which have a strong repulsion for one another, while they are attracted by the other kinds of matter, and that with different degrees of force. . . . Such an idea of the nature of heat is therefore the most probable of any I know ; it is, however, altogether a supposition." Black then divides his treatment of the action of heat into five sections, namely, Expansion, Fluidity, Vapour, Ignition or Incandescence, and Inflammation or Combustion. Under the heading " Expansion," he deals with the general law that heat produces expansion, and considers exceptions ; and he treats of the " non-ponderosity " of heat. In the second, the construction of thermometers ; and in this section

he notices the very important experiment, made by Dr. Brook Taylor in 1723, of mixing a known volume of water at a known high temperature with an equal volume at a lower temperature, and "learning whether the quicksilver is expanded by different heats in proportion to the differences of these heats." This experiment was also made by Black "in the year 1760, at which time I did not know (as I said just now) that it had been made or thought of by any other person." He thus proved that "the expansions of quicksilver, while it heated slowly, from the cold of melting snow to the heat of boiling water, are very nearly proportional to the additions of heat by which they are produced."

An interesting point in connection with the mercurial thermometer is its ceasing to indicate temperature owing to the freezing of the mercury at very low temperatures. Black was in correspondence with Mr. Hutchins, one of the servants of the Hudson Bay Company, with regard to this; and gave him instructions how to proceed in determining the freezing-point of quicksilver; he also directed Dr. Guthrie at St. Petersburg; and it appeared that it freezes at minus 40 or 41° Fahrenheit.

He then devotes some time to what we now term specific heats; and describes an experiment made by Fahrenheit, in which mercury at 150° was mixed with water at 100°; the resulting temperature was not 125°, but 120°. "The quicksilver, therefore, is become less warm by 30 degrees, while the water has become warmer by 20 degrees only; and yet the quantity of heat which the water has gained is the very same quantity which the

quicksilver has lost. This shews that the same quantity of the matter of heat has more effect in heating quicksilver than in heating an equal measure of water, and therefore that a smaller quantity of it is sufficient for increasing the sensible heat of quicksilver by the same number of degrees." He goes on to say that each substance must attract its own particular quantity of heat ; " perhaps not any two of them would receive precisely the same quantity, but each, according to its particular capacity, or its particular force of attraction for this matter."

The loss of heat by convection next occupies his attention ; and he alludes to the function of clothes in retaining heat, and the action of the wind in distributing it.

Under the heading " Fluidity " the following passage occurs : " Fluidity was universally considered as produced by a small addition to the quantity of heat which a body contains, when it is once heated up to its melting-point ; and the return of such a body to the solid state, as depending on a very small diminution of the quantity of its heat, after it is cooled to the same degree ; that a solid body, when it is changed into a fluid, receives no greater addition to the heat within it than what is measured by the elevation of temperature indicated after fusion by the thermometer ; and that when the melted body is made again to congeal, by a diminution of its heat, it suffers no greater loss of heat than what is indicated also by the simple application to it of the same instrument.

" This was the universal opinion on this subject, so far

as I know, when I began to read my lectures in the University of Glasgow, in the year 1757. But I soon found reason to object to it, as inconsistent with many remarkable facts, when attentively considered ; and I endeavoured to shew that these facts are convincing proofs that fluidity is produced by heat in a very different manner."

Black's next great contribution to science may now be shortly told ; it is fully described in his lectures ; but these, it must be confessed, are, though very clear, somewhat verbose.

Between the years 1759 and 1763 he had formed opinions regarding the quantity of heat necessary to raise equally the temperatures of different substances. Boerhaave imagined that all equal portions of space contain equal amounts of heat, irrespective of the nature of the matter with which they are filled ; and his reason for this statement was that the thermometer stands at the same height if placed in contact with objects near each other. Here we have a confusion between heat and temperature ; and this was perceived by Black, for he pointed out that a distinction must be drawn between *quantity* and *intensity* of heat : the latter being what we now call *temperature*. He quotes Fahrenheit to show that while equal measures of water at different temperatures acquire a mean temperature when mixed, it requires three measures of quicksilver at a high temperature to convert two measures of water at a low temperature to the mean of the two temperatures ; and this corresponds to twenty times the weight of the water. Black expressed

this by the statement that the capacity for heat of quicksilver is much less than that of water.

But before this, in 1757, Black had made experiments leading up to these views. He had noticed that when ice or any solid substance is changing into a fluid, it receives a much greater amount of heat than what is perceptible in it immediately afterwards by the thermometer. A great quantity of heat enters into it without making it perceptibly warmer. Conversely, in freezing water or any liquid, a large amount of heat comes out of it which again is not revealed by a thermometer.

He then proceeded to estimate the quantity of heat which had to be absorbed by a known weight of ice in order to melt it. He hung up two globes side by side, about 18 inches apart, in a large empty hall, in which the temperature remained practically constant; each globe contained 5 ounces; one of ice at 32° F., the other water at 33° . The latter had a delicate thermometer suspended in it. The temperature of the hall was 47° F. In half an hour the water had attained the temperature 40° F.; and the ice took ten hours and a half to attain the same temperature, that is, twenty-one times as long as the water. The heat which the ice absorbed during melting was $(40-33) \times 21$, or 147 units; that is, had it been absorbed by the five ounces of water it would have made it warmer by 147° . The temperature of the ice, however, was 8° warmer than its melting-point, after the 21 half-hours; hence 139 or 140 "degrees had been absorbed by the melting ice, and were concealed in the water into which it had changed."

The method of experiment was next varied. Black weighed a lump of ice, and added it to a weighed quantity of warm water of which the temperature was known. The warm water was cooled to a much lower degree by the melting of the ice than if it had been mixed with a quantity of water of 32° F. equal in weight to the ice. The quantity of heat absorbed by the ice in melting appeared from this second experiment to have been capable of heating an equal quantity of water through 143° F.

A third experiment was made, in which it was proved that a lump of ice, placed in an equal weight of water at 176° , lowered the temperature of the water to 32° . Now $176 - 32 = 144^{\circ}$,—again a similar result. The latent heat of water is therefore about 142 or 143, in Fahrenheit units. The result of the most careful measurements give 79.5° centigrade units, which corresponds with 143° units of Fahrenheit's scale. Curiously enough, this fundamental datum has not yet been determined with the accuracy which is customary nowadays; and it is still uncertain to one seven-hundredth of its value. Black's determination was a remarkably good one, especially if we consider the crude appliances which he used.

The substance of this research was communicated to the "Philosophical Club," or society of Professors and others in the University of Glasgow, in the year 1762; and was expounded yearly by Black in his lectures to his students.

Similar experiments were made by Black on the latent heat of steam, in which he compared the time required for a known weight of water to rise through a definite

interval of temperature when exposed to a constant supply of heat with that required to dissipate the water into steam. But his estimate of 830 units required to evaporate one part of water was not so accurate; the actual figure is 967 units on the Fahrenheit scale. Black cited experiments by Boyle, by Robison, his successor in the Glasgow chair, and by Cullen, his predecessor, in which the boiling-point of liquids had been found to be lowered by reduction of pressure; he rightly ascribes this to the freer escape of the vapour, and to the absorption of heat by the vapour, and the consequent cooling of the liquid from which it is escaping.

These conceptions of Black's were utilised by his friend James Watt in his work on condensers, and, as everyone knows, effected a revolution in the structure of steam engines, and as a consequence in the whole of our industrial and social life; and, further, they were developed by many men of science, until in the hands of the masters—Joule, Clerk-Maxwell, Rankine, James Thomson, and Kelvin, on the physical side, and of Willard Gibbs, the American, on the chemical side—they form the very groundwork of the sister sciences, physics and chemistry.

Black's great chemical discovery that a gas exists which is clearly not a modification of atmospheric air, seeing it can be "fixed" by alkalies and alkaline earths, led the way to "pneumatic chemistry," as it was called, and was followed by the discovery of oxygen by Priestley, of nitrogen by Rutherford, of hydrogen by Cavendish and Watt, and of the more recent discoveries of argon and its congeners, all of them constituents of the atmosphere.

And Black's proof, that the change of a complex compound to simpler compounds, and the building up of a complex compound from simpler ones, can be followed successfully by the use of the balance, has had for its consequence the whole development of chemistry.

From 1726 to 1755 Andrew Plummer, a pupil of Boerhaave and a graduate of Leyden, had filled the Chair of Medicine and Chemistry in the University of Edinburgh; he lectured chiefly on chemical pharmacy. On his death in 1756, Black's teacher, William Cullen, succeeded him in the vacant Chair, having been called the year before from Glasgow to assist him as joint Professor. It will be remembered that Black succeeded Cullen in Glasgow, where he lectured until 1766. In that year Cullen was transferred to the Chair of "Institutes of Medicine," and the Chemical Chair was again vacant in Edinburgh; Black was called to succeed him. Lord Playfair, in an address which he gave in Edinburgh, entitled "A Century of Chemistry," said in regard to Cullen: "He saw that a science like Chemistry was not to be taught by mere lectures, but that there must be a free and unreserved communication between the teacher and the taught. He cultivated the personal acquaintance of his pupils, and zealously aided them to overcome their first difficulties." It is said that Cullen's clearness of exposition was remarkable, and that he was the inventor of diagrams, the precursors of chemical equations, which showed the results of reactions by means of lines joining the reacting bodies; an example is to be seen on page 25.

A sketch of Cullen in his later years, executed by John

Kay (A Series of Original Portraits and Caricature Etchings, Edinburgh, 1837), is reproduced here.

The Professors in the University of Edinburgh had recommended Black for the Chair of Chemistry ten years before, in 1756 ; but the Town Council, who had almost absolute power over the University, were then opposed to his election, and gave the preference to Cullen. Indeed, the history of that University consists in great part of wrangles between University and Town Council, as may be seen from *The Story of the University of Edinburgh*, by its late Principal, Sir Alexander Grant (Edinburgh, 1884). During Black's tenure of the Chair, however, peace prevailed, as a rule ; but at the beginning of last century, the strife was almost incessant, until it ended in 1858, when a new constitution was drawn up by a Royal Commission.

The buildings now standing were preceded by a set of houses dating from the year 1583, when the Town Council opened the College. It consisted of Hamilton House and the " Reid Chambers," and a few years later, of the Manse of the Kirk-of-Field, which became the residence of the Principal. Hamilton House was fairly large ; it contained a hall, five classrooms, and three sleeping apartments ; the Reid building contained fourteen, and the Manse four sleeping chambers. A library and hall were added in 1616, and in 1640 the west side of the College court was built, with a series of rooms ; other buildings were added in 1664. In 1768 Principal Robertson, describing the College as it appeared in his time, wrote : " A stranger, when conducted to view the



WILLIAM CULLEN, M.D.

From Kay's portraits

a house for the Professor of Chemistry, contiguous to his laboratory, was, in his view, a necessity ; but such a house was never erected.

Among Black's colleagues and intimate friends were Dugald Stewart, at first Professor of Mathematics (1772-85), and later (1785-1828) of Moral Philosophy ; his philosophical works rendered him famous over all the world. John Playfair, the biographer of Hutton, succeeded Stewart in the Chair of Mathematics ; the nominal Professor, to whom he acted as colleague, was Adam Ferguson, to whom Dugald Stewart had succeeded as Professor of Moral Philosophy. As may be noticed, there was a good deal of shuffling of the cards ; the powers of the Professors appeared to be of an encyclopædic character.

During Black's student days in Edinburgh, as has been already stated, he lived with his cousin, James Russell, who was then a surgeon in practice. In 1764 another shuffling of cards took place : Bruce, the Professor of Public Law, was bought out ; James Balfour replaced Bruce ; he subsequently sold his chair for £1582 15s. 2d. to his successor, Maconochie. Adam Ferguson replaced Balfour, leaving the Chair of Natural Philosophy vacant ; to this Russell was appointed, having contributed his fraction to the purchase of Bruce's chair. The Town Councillors were the electors, and no doubt means were taken to secure their support in engineering all these changes. On Russell's death, in 1773, John Robison, Black's biographer, and the editor of his Lectures, succeeded to the Chair of Natural Philosophy. He is

said to have possessed "extraordinary powers of conversation."

Daniel Rutherford, a pupil of Black's, whose thesis on Mephitic Air announced the discovery of nitrogen, was appointed to the Chair of Botany in 1786. He was uncle to Sir Walter Scott, his sister having married Scott's father. Sir Robert Christison relates that "Tradition had it in my student years that he was disappointed at not being made Assistant and Successor to Black in 1795"; the appointment was bestowed on Charles Hope, son of the Professor of Botany, who at that time held the Professorship of Chemistry in Glasgow, having succeeded to Black there. It was he who first described strontia; and his name is also associated with the discovery of the fact that water has a point of maximum density at 39.1° F.

These were the men with whom Black was intimately associated as colleagues in the University. They were all men of distinction, known to the world by their work; but their habitation was not worthy of them. However, to translate a German proverb: "No matter what the cage is, if but the bird can sing?" and all the names of these distinguished men testify to the truth of the saying.

CHAPTER IV

IT is generally possible to gather from a man's correspondence not merely an idea of his manner of life, but also of his character. Black kept no diary, but as has already been remarked, he was exceedingly methodical and exact, and the letters which he wrote and received throw much light on the way in which his life was spent. Many of the letters are from men whose names have become of world-wide fame; others are from foreign correspondents; many are from old students; a few are from his relatives. I shall attempt here to extract from them such matters as appear of personal or of general interest.

It may be remembered that in September, 1763, Black wrote to his father saying that he "had wrote a paper on the use of lime in bleaching." That letter, addressed to Dr. Ferguson at Belfast, is the first of the correspondence. He begins by referring to his previous reports, and continues: "All the chemists agree that lime loses a great part of its weight on being burnt. That this loss of weight is occasioned by the dissipation of an aerial matter is clear from a consideration of Markgraaf's." Black then refers to his own experiments made in 1752-4, in which he established the nature of lime and

of "fixed air." He is doubtful as regards the use of quicklime in bleaching, and in this connection he adds: "Yet I have a suspicion that lime will not be so much softened by solution as salts; my reason, I confess, is rather too subtile, but I shall give you it for your private amusement. The most corrosive salts are rendered harmless by copious dilution, because each of their particles is surrounded with a larger quantity of attracting water, which chiefly by its attraction for them, and partly too by keeping them more *épars*, diminishes their disposition to unite with or attack other bodies. But the attraction of dissolved lime and water is incomparably greater than that of the non-corrosive salts and water, and hence will have less effect; this I take to be one reason why lime-water is so sharp upon cloth. You may see how this circumstance retards the junction of salts with one another in hitting the point of saturation with a diluted acid and alkali, and will find that a brisk agitation with a glass rod or y^e handle of a teaspoon, by throwing some confusion into the arrangement which the attraction of water occasions will promote the union and effervescence after everything seems to be quiet." Here Black seems to have made some forecast of molecules and their attraction. After discussing the conversion of quicklime applied to cloth into chalk, by the fixed air in the atmosphere, he dissuades Dr. Ferguson from using dilute vitriol for this purpose; the gypsum would be very difficult to remove from the fibre, owing to its sparing solubility in water; moreover, "soaping the cloth would make it become greasy, the acid deserting

y^e earth to unite with the salt of the soap, and that separating y^e oil." He does not recommend "buttermilk sours" (lactic acid) or vinegar, because their attack of chalk is so slow. "The reason of this too is plain and easy. There is no substance that attracts and retains mephitic air so strongly as do the calcareous earths; they therefore attract it very near as strongly as they do these very weak acids (by weak I do not mean dilute, but less active or powerful) and hence these acids expel the air slowly and as it were with difficulty." We have Dr. Ferguson's reply to this letter, which need not be further considered; but it appears that the upshot of the correspondence was that the Linen Board of Belfast prohibited the use of lime in bleaching.

James Thenley, who conveyed this information to Black, was anxious to get particulars of the manufacture of "the vitriolic acid" from sulphur, as carried out at Newcastle and at Prestonpans; and Black replied: "I am intimately acquainted with Dr. Roebuck, the contriver and principal proprietor of the work at Prestonpans, but he never dropt the smallest hint to me upon the subject, & as I know that they are at great pains to keep it a secret as being a very lucrative business, I never presumed to shew any curiosity with regard to it. I am therefore perfectly ignorant of the method they use."

The method was invented by Dr. Roebuck, of Birmingham, in 1746; it consisted in the substitution of chambers of lead for the glass globes formerly in use; in 1749 works were erected by Roebuck and Garbet at Preston-

pans. The cost was then about £30 per ton of sulphuric acid ; it is now about 30s.

Among the letters received about this time was one from Mr. Alexander Wilson, who sold thermometers ; he offers small ones for a guinea, and the " boiling-water ones " at a guinea and a half ! Truly chemistry was an expensive pursuit in these days !

In 1770 Black received from Lord Hopetoun samples of the soil of the Leadhills, a district in the upper part of Lanarkshire, for examination. He found it to contain 179 grains of gold per ton, besides lead ore (galena), iron pyrites and magnetic ore, as well as small garnets. Another batch contained spar with veins of " black-jack " or zinc-blende ; there was also kupfer-nickel, and from this Black prepared some " niccolum," which he sent to Lord Hopetoun.

In the same year he was asked to examine the water supply of Newcastle-upon-Tyne, obtained from a spring at Coxlodge ; six bottles were sent by the carrier. Black's answer and report are quaint ; he says : " If I were writing to the Gentlemen who were to determine and direct in this matter, I should certainly stop here, well knowing what perplexity is often occasioned by speaking to People a Language which they do not understand." He then explains that " soft and good Δ 's contain from 5 to 40 grains of fixed matter from each gallon, & that hard waters contain from 40 to 120 grains, according to the distinction of good Δ 's from bad." A gallon of the Coxlodge water was evaporated in a glass bowl, and left a residue weighing 28 grains ;

the residue "consisted of earths, mostly calcareous, and a fixed alkali, the latter prevailing very much amounting to 23 of the $28\frac{1}{2}$ grains combined with the fossil acids. If we may venture to judge *a priori* therefore, I should expect that the water should draw strong and deep coloured infusions from tea, malt, and other vegetables, and would prove remarkably soft for all æconomical purposes & for bleaching linnen; and with regard to its wholesomeness, I cannot conceive that the fixed alkali is less innocent than the gypsum and other earthy compounds that water commonly contains."

In 1772, at the wish of Lord Hopetoun, Black visited the Leadhills, and made a report on the gold in the streams of that neighbourhood. He found gold in the river sand, and recommended a trial on the rock of the country, by aid of a stamping-mill. In the sand he found ninety-seven grains per ton. This was obtained by washing and then cupelling the galena left in the dish; to remove silver the operation of parting was resorted to. Each particle of galena had adhering to it a particle of a "compound of arsenic, iron, and some cobalt, from which it appears that there is a vein of cobalt somewhere in these hills." He gave Lord Hopetoun designs of a mechanical washer which he had invented, and which, he says, would cost three or four pounds.

We next find a correspondence with Black's intimate friend, the celebrated James Watt, with reference to the Crinan Canal, piercing the neck of the Mull of Cantyre, which was then being projected. Watt had made a survey, and estimated the expense of a ten-foot canal as

£49,000. Watt finished his letter : " I hear of an acid somebody has discovered that turns water into flint ; do you know anything of it ? " But to this Black makes no reply.

Black received numerous letters from old students of his, who had settled in various parts of the world. One, written by a Mr. Alexander, settled at Bacolet, Grenada, West Indies, begins by thanking him for the pains Black had bestowed on his instruction, and then goes on to describe a disease affecting negroes, named " the yaws," and gives methods of cure practised by the negroes themselves. The letter then gives a statement of the rainfall at Grenada, from September, 1772, to March, 1773, amounting to thirty-seven inches. A later letter deals with the large amount of " mephitic air," meaning carbon dioxide, in Grenada ; for quicklime rapidly becomes " bad." He also discourses on sugar boiling at his plantation, and criticises Franklin's theory of water-spouts. The replies which Black sent to these letters are not extant

During the year 1775 many letters passed between Black and Henry Home, Lord Kames, on the nature of solution. Lord Kames imagined that an emulsion of clay in water differs only in degree from a solution of salt in water ; Black tries to point out differences, but fails to convince Lord Kames. The last letter to Black, which finished the correspondence, begins : " Sir,—This is Sunday morning, and I figure myself applying to you as Abraham did to the Lord, ' Behold, now I have taken upon me to speak unto the Lord, which am but dust

and ashes.' Your response has not satisfied me more than the response of the Lord did Abraham." Black retorts that Lord Kames does not read his letters with care and attention ; and the correspondence then ceases.

The year 1776 opens with the first of a long series of letters from M. L. Crell, the editor of *Crell's Annalen*, a former Continental journal, resembling our *Philosophical Magazine*. Crell had been a student of Black's. In his opening letter he writes : " I wish I had an opportunity to send you some papers and dissertations I have published ; my greatest reward would be your not disapproving of them. The chief of them is a Chemical Journal wrote in German ; I don't remember if you understand it." For many years Crell sent to Black succinct accounts of the progress of chemistry on the Continent ; these will be noticed later. Another foreign correspondent was Mr. Hermann, Advocate-General of Strassburg, for whose mineralogical collection Black had provided many specimens.

A new chemical laboratory in Edinburgh was built in 1781, or to be more accurate, other and better accommodation was provided for chemistry in a portion of the old buildings ; Black was employed during that year, he tells Patrick Wilson, son of the Professor of Astronomy in Glasgow College (who was then assistant to his father, Alexander Wilson, and succeeded him in the chair in 1784), " in flitting a vast rubbish of things and experiments from the old laboratory." Wilson made many experiments on snow crystals, and found the temperature of the air in their neighbourhood much higher than that of the snow.

Black confesses himself unable to explain this. He suggests that the "gradual solution of the snow by the air, which you seem to suspect, appears to me scarcely distinguishable from evaporation." Dr. Wilson having stated that ice expands when cooled, Black, though doubtful of the fact, explains it by a possible absorption of heat on expansion. He draws attention to an evolution of heat on contraction, shown by the rise of temperature during the hammering of metals, which increases their density; heat is also evolved when alcohol is mixed with water, or when vitriolic acid is mixed with water, and in both cases there is contraction. Again, exhausting the receiver of an air-pump, which is virtually an expansion of the air, produces cold. It is interesting in the light of present knowledge to look back on such remarks, which showed Black's power of generalisation in suggesting a connection between apparently unconnected phenomena.

In 1782 prizes were offered by the Dublin Society for alkali made from kelp, or dried seaweed, and also to encourage the manufacture of kelp. Indeed, the manufacture of cheap alkali was at this time becoming a pressing question, for kelp, containing only a small percentage of carbonate of soda, sold for twenty or twenty-two pounds a ton. Black gives elaborate notes, taken from a memorial presented by E. Macculloch to the convention of boroughs in 1782; the alkali was to be used for soap-making and bleaching. The "ashes" used for alkali manufacture were generally produced from "Gentlemen's woods in England." They were made by filling a conical hole in the ground, a yard wide

at the top and a foot at the bottom, with wood-scrap ; and after setting it on fire leaving it to smoulder for a fortnight. The price of "pearl-ash," or fairly pure potassium carbonate, from abroad, varied from fifty to seventy pounds a ton. The value of the import was at that date about £50,000 per annum.

In 1783 Dr. Heysham sent Black a specimen of a dark-coloured powder found near Ashburn, in Derbyshire, which, when moistened with linseed oil, gives a mixture which ignites in about ten minutes. Black identifies it as a compound of black magnesia (manganese) ; it is probably finely divided peroxide. "The miners call it very improperly black wad." It is now well known that the presence of compounds of manganese cause linseed oil to "dry," or oxidise, more rapidly ; and this may happen, apparently, with such evolution of heat as to inflame the oil.

Black's was a cautious nature ; he did not commit himself to the doctrine of phlogiston, then universally held. This doctrine, originally propounded by Stahl, was that when a body burns, a light, subtle material escapes ; to this he gave the name "phlogiston." The residue, which we now know to be the oxide, was then termed the "calx," and was imagined to be the metal or other combustible body, less the phlogiston, which it had contained before burning. By heating a calx with some substance rich in phlogiston, such as charcoal, the calx absorbed phlogiston from the charcoal, and the metal was regenerated.

In March, 1783, Dr. Quin, writing from London,

desires Black's opinion regarding what had been told him by Dr. Kirwan, that Bergmann had measured the amount of phlogiston in silver, by precipitating a known weight of it from its nitrate by copper ; the copper, going into solution, he believes, contains the phlogiston which has escaped from the silver. Lead precipitates the copper, and iron the lead ; and the relative weights of these metals must all contain the same amount of phlogiston. This, according to our modern views, is an inverted statement of the truth. If we read for " phlogiston " " removal of oxygen," such experiments would give us the equivalents of the metals. According to still more modern views, the precipitation of silver by copper involves the transference of electrons, or particles of negative electricity, from the copper to the silver ; and the relative weights of metals, precipitated one by another, are combined with the same number of electrons.

Dr. Quin also suggested that Priestley's " dephlogisticated air," now known as oxygen, is fixed air, less the principle of inflammability ; in a sense, too, this is right ; for fixed air is not combustible ; it is a compound of oxygen with carbon, and if the combustible matter, the carbon, be removed from it, oxygen remains.

Black was not " drawn " by this letter ; he did not answer Dr. Quin for a year, and then did not refer to the subject.

His attention at this time was much occupied by advising on improvements in the manufacture of cast and wrought iron ; but in a long report which is extant there is nothing that calls for special notice.

A correspondent sends Black an account of a method of heating water practised in Canada. Pour a few spoonfuls of water on the top of the stove, and quickly set the kettle on the spilled water. Black's comments are : " Upon further consideration it appeared to me that this practice was one of the best illustrations of the Doctrine of Latent Heat ; for the small quantity of water thrown upon the stove is instantly converted into vapour, and striking against the bottom of the kettle is thereby condensed into drops, at the same time communicating a large quantity of latent heat to the kettle. These drops now fall down from the bottom of the kettle to the stove, and are again converted into vapour. Hence it happens that this small quantity of water, alternately suffering expansion and condensation, is not dissipated even by a very hot stove, but for a considerable time passes backwards and forwards between the stove and the bottom of the kettle, becoming a carrier of heat in the same manner that pieces of gold-leaf become carriers of electricity between two plates, one being suspended above the other." Black made comparative experiments, and found that while the water in a kettle placed directly on the stove had attained 63° F., 102° were reached in the same time by a kettle thus treated.

During the months of January and February, 1781, Dr. Pat Wilson, the Glasgow astronomer, described to Black experiments which he had made during a spell of cold weather. He mixed alcohol with snow, when the temperature fell from 24° above zero Fahrenheit to 28°

below zero, a drop of 52° . He also covered the bulbs of thermometers with hoar-frost, and whirled the instruments round at the end of a piece of packthread ; but the temperature did not fall ; naturally, the fall would depend on the hygrometric state of the atmosphere at the time ; it was probably saturated with moisture. Wilson also mentions that having placed in a Torricellian vacuum a thermometer, he noticed no rise of temperature when the empty space was lessened in volume, and no fall when it was increased. He appears to have imagined that the lowering of temperature when the volume was increased would be so great that some of the mercury would freeze ; but he gives no reason for this surmise. He mentions incidentally that he has taken a copy of the letter which Black received by help of " Mr. Watt's new copying machine," which, it would appear, had then only recently been introduced.

Black's comments on Wilson's observations are of no particular interest and need not be quoted.

A certain Dr. Price, in November, 1782, whose former name was Higginbottom, is reported on to Black by Mr. William Thomson, of Christchurch, Oxford. Apparently he claimed to have manufactured gold, and he published an account of this in the *Gentleman's Magazine* ; and, according to Thomson, his statement is " nothing but a mass of errors throughout." In his reply, Black expresses his surprise that a degree should have been conferred on Mr. Higginbottom by the influence of Dr. Wall, for " knowledge, ingenuity, and skill in experiments." " I thought it was necessary, however, to take

some notice of the pamphlet in my introductory lecture this season, but my only intention in this was earnestly to dissuade my pupils from giving way in the least to the ruinous notions and pursuits of Alchemy, which Dr. P.'s publication, so far as it may be credited, would have a tendency to encourage. I reminded my audience that numerous experiments to prove the possibility of transformation had been formerly exhibited or described which were afterwards discovered to have been founded on mistakes or frauds; and observed that the present age does not require incentive to experimental enquiries, with a view to deterring my young friends from entertaining alchemical Notions or Projects." Dr. Wall excuses himself for the part he has played; and a final letter from him closes with the words: "Whatever other defects we may have, an attachment to y^e hermetic Philosophy makes no part of our character."

In June, 1782, Black was consulted on the water supply of Leith; he made no analysis, but characterised the water as "disgusting and slimy."

We now come to a very interesting piece of history, namely, the process for manufacturing alkali, generally associated with the name of the French chemist Leblanc. The world's chief source of soda, before the year 1780, was kelp, or barilla. The manufacture of kelp was carried on at a very early period on the north and west coasts of Ireland, where "tangle," a flat-leaved seaweed, of which the botanical name is *Fucus palmatus*, grows in very large amount; later, large quantities of kelp were produced on the islands and coast of the West of Scotland.

The seaweed was dried and burnt ; the ashes consist largely of sodium carbonate, or "soda," and when treated with water the soda dissolves, and the solution, when evaporated, gives crystals of "washing soda" ; if dried up, the powder is called "soda-ash," and a specially pure variety is termed "pearl-ash." The same process was carried out on the Spanish coast, and the product was "barilla" ; the plant there burned was the *Salsola soda*, cultivated on the coast of Spain.

This trade in Britain was particularly brisk during the Peninsular War, for the sources of Spanish barilla were cut off ; and the import of barilla into France ceased at the time of the French Revolution in 1789. The National Convention made a special appeal to the French chemists to help them ; and this was stimulated by the offer of a substantial prize. Nicolas Leblanc is said to have begun his experiments in 1784 ; in 1789 he submitted his plans to the Duke of Orleans, from whom he received pecuniary help ; and in 1791 the process was patented. In 1794 the Committee of "Salut public" made Leblanc give up his patent for the benefit of his country, and awarded him the munificent sum of £24 to recoup him for his losses. He persisted in his claims ; and in 1806 he received a reward, but so small a one that in despair he committed suicide.

To understand the position in the year 1783 it must be realised that there was a duty on salt in Great Britain of £30 a ton ; and that the available soda was very impure ; soda from Alicant contained 26 ; Sicilian soda, 23 ; that from Narbonne, 14 ; Norwegian kelp, 6 ; and Scottish kelp, 3 per cent of anhydrous carbonate.

Leblanc's soda process consisted in (1) treating common salt with sulphuric acid ; by this, hydrochloric acid comes off as a gas and " salt-cake," or sodium sulphate, remains. (2) The salt-cake was mixed with powdered coal and carbonate of lime, in the form of limestone or chalk ; the mixture was heated in a furnace. (3) The heated mixture, or " black ash," was treated with warm water ; the water dissolved out the carbonate of soda, while the residue, called " soda-waste," consisting of calcium sulphide, was piled into heaps, having been rejected. (4) The solution of sodium carbonate was boiled down and left to crystallise, when " soda crystals " were deposited, and were sold as " washing soda " ; or the liquid was boiled to dryness and left " soda-ash " ; or quicklime was added to the liquors ; this " causticises " them, and converts the soda into " caustic soda," of use in soap-making.

In 1781 Dr. Brian Higgins, in England, had nearly forestalled this process ; but instead of heating the salt-cake with coal and lime he heated it with coal alone ; this reduces the sulphate to sulphide. The next step was to fuse the sulphide with lead, and to stir it with an iron rod ; the sulphur united with the lead, and caustic soda floated on the top of the melted sulphide of lead. This process failed owing to the high price of lead ; but Higgins suggested replacing the lead with iron, or the use of other metallic oxides ; had lime been specified, Higgins's process would have been identical with Leblanc's. Iron was used in 1775, as appears in a letter from James Keir to Black, dated August 8th, 1782. He complained to

Black that Fordyce had patented a process which he (Keir) had practised for seven years.

We now return to Black's letters. On February 7th, 1782, he received a letter from Messrs. John Collison and Co., Southwark, with a sample of soda, which they asked Black to test; they say: "We have now entered into the manufacture of alkaline salts from a conviction that we can make them of a quality much better than any that ever were imported." They enclosed a copy of their patent, which runs as follows. It is headed "Making vegetable and mineral alkali."

"Now know ye that in compliance with the said proviso, I the said John Collison do hereby declare that the nature of my said invention of a new plan or method of producing or making mineral or vegetable alkali and the manner in which the same is to be performed is described and ascertained in the manner following, that is to say: as to for touching or combining mineral alkali.

"I take Glaubers Salt, or any substance or liquor containing Glaubers Salt, or I take rock-salt, sea-salt, or common salt, and any substance or liquor containing vitriolic acid, and mix these so that the salt shall be nearly twice the weight of the concentrated vitriolic acid, which I heat together in an open fire, reverberatory furnace, iron pot, or other utensil, together with from a quarter to a half its weight of some or one or more of the following substances, videlicet, mortar, Sopers' ashes, gypsum, loam, calcareous or other earth, and the same quantity, more or less according to their different qualities, of horns, hoofs, hair, leather scraps, pitch, tar,

small vegetables, Breeze, Charcoal, Pit-coal, or any other substances containing, or supposed to contain an inflammable principle or phlogiston, or some, or one, or more of them ; which, when properly heated, melted, or fluxed, produce a mineral alkali. And as to for touching and concerning the vegetable alkali, I pursue the same process as above, except that I take Sal Polychrest, vitriolated tartar, or any substance or liquor containing vegetable alkali and vitriolic acid, instead of the salts and mixtures above mentioned."

This patent, in its quaint phraseology, is virtually Leblanc's process. Black examined the product and found it "to be very strong and powerfull. It contains more alkali than the best Alicant barilla in the proportion of 68 to 44, and more than the best kelp in the proportion of 68 to 10. There is no need to use lime in drawing the leys from it, as it is already in a caustic state."

I have failed to trace the history of Collison's works ; in all probability the manufacture was killed by the enormous duty on salt. Immediately after the abolition of the salt tax in 1823 James Muspratt started alkali works in Liverpool ; and for six years they were the only ones in Great Britain. His descendants still carry on the manufacture in conjunction with the United Alkali Company. But this glimpse into the past shows that as usual England was to the front in the applications of chemical discovery, and that Leblanc was not the first to use the process which goes by his name.

A year later, in answer to a request from Black for information, the Rev. Dr. John Stuart, Minister of Luss,

Loch Lomond, describes the burning of bracken (*Pteris aquilina*, Linn.) in a pit to white ashes, containing carbonate of potassium. This used to be carried on in Inch Murrain, one of the numerous islets on the loch, but had then been abandoned, for the price of ashes had been reduced by one-third. The minister, however, induced two of his parishioners to burn some, and sent two bottles to "the Doctor."

On January 15th, 1784, Black was consulted about the establishment of works for the manufacture of "fossil alkali," or soda, by Mr. James Gerard, surgeon, in Liverpool. Gerard says that as the duty on salt is now lowered, it is a favourable time to consider such an undertaking, and Liverpool is a suitable place for such a manufacture; he proposes to make sal ammoniac, sulphuric acid, Glauber's salt, and alkali. He adds: "I have copies of Dr. Higgins's, Fordyce's and Collison's patents, if you wish to consult them. The last is artful and intricate. I am told it answers, as also a work carried out at Birmingham by Keir, Bolton and Watt."

Black's answer is not preserved; but on June 7th Gerard wrote: "I am concerned and disappointed to find that I must not expect your assistance in the alkali pursuit." He does not reveal his own process; he merely says that he gets as much alkali from 4 oz. calcined Glauber's salt as will convert 3 oz. of tallow into good soap; he also gets sal ammoniac as a by-product. Can this be a foreshadowing of the ammonia-soda process?

During the year 1782, too, there are several letters from Crell. His great appreciation of Black is the invariable

beginning of all his letters; in the first he alludes to "the very great esteem I bear (along with all chemists) for you as one of the greatest chemists now living." "I acknowledge with a very grateful mind how much I am indebted to you as my great teacher in chemistry; and this very gratitude shall never cease during my life." In another letter he assures Black "how much I esteem your open, sincere, and friendly character." As usual, he informs Black of chemical novelties thus: "The Count Sickingen has detected the way of making the Platina ductil, and finer wires of it than of ☉. He dissolves it in R, and takes the ♂ out by lixivium sanguin, calcines the platinum salt, and beats it while hot with the malleus on the incus." In modern language, he dissolves the platinum in nitro-hydrochloric acid, precipitates it with ammonium chloride, and by heating to redness produces spongy platinum, which he hammers on an anvil while hot. Another piece of news is: "To tinge cotton with madder as constant as the Turkish garn is: You infuse cotton with olive oil, or the oil from the whale, press it out, to take the superfluous part away, by a lixivium of hot caustic alkali, boil it with a lixivium of *Rhus coriaria* and galls; and being dried, again with the decoction of madder."

To these letters Black replied in September, 1782: "I now sit down to return you my most sincere and hearty thanks for the chemical news with which you have favoured me at different times, and which consist of such a number of articles that I shall find difficulty now to take notice of them all, tho there are none but what are

curious and interesting." His comments are of no special importance.

Ammonia used to be made by allowing urine to putrefy and distilling it.

In reply to a request from Black, Mr. George Macintosh, of Glasgow, sent him some of the "caput mortuum," that is, the residue from his still, one capable of holding 4000 gallons of liquid. Incidentally Macintosh asks for suggestions about mordanting cloth, and Black mentions bismuth as perhaps suitable in some cases.

In October of that year a request arrived from Mr. John Maitland that Black would admit into his class a poor boy of undoubted ability, and the request is at once cordially granted.

On January 25th, 1783, a letter from Dr. Guthry [*sic*] arrives from St. Petersburg, of which Black made extracts; it is what he bases his lecture on Heat on (p. 39). "He was able to freeze ϕ by mixing snow and $\phi >$ when the thermometer was at 20 to 24 below 0 of Reaumur, which, says he, is =46 & 54 degrees below frost of Fahrenheit or to 13 & 22 below 0. The ϕ was frozen in a glass tube $4\frac{1}{2}$ in. high & 1 in. diam. set in a freezing-mixture of snow & $\phi >$ contained in an English water-glass wrapped up in furr to the brim. The ϕ stood at 41 of Reaumur=60 degrees of Fahrt., & it stood there during the rest of the process untill all the ϕ in the tube was congealed."

CHAPTER V

IN the beginning of 1783 the first high honour was conferred on Black, by the Imperial Academy of St. Petersburg ; he received a letter from the Prince Dashkow, from which this is a sentence : “ The many kind instructions and all the good offices I received from you during my stay in Edinburgh encourage me to interrupt your more serious occupations, the more so, as it is to inform you that you were elected Honorary Member of the Academy of Sciences here. It was my dear Mother whom the Empress made a few days ago Director of the Academy who proposed you.” To this Black replied : “ I cannot express the deep surprise and gratitude which I felt on receiving your letter of the 29th January last, by which you inform me that I have had the high honour to be proposed by the Princess Dashkow and elected by the Imperial Academy of Sciences an honourary Member of that Learned & Celebrated Assembly. . . . It is the first honour of that kind I have received, and I shall always consider it the greatest I can receive.” Jean Albert Euler sent Black his welcome to the Academy on the 24th February, and Black answered in faultless French ; he had evidently not forgotten the language of his youth. He was in doubt, however, how to address the Princess, and applied

to Principal Robertson · “ Be so good as to inform me (in two words at the foot of this) how you address the Princess in the beginning of your letter.” The answer is : “ I have always addressed the Princess ‘ Madam,’ and the Prince ‘ Sir,’ without any ‘ Highness.’ ” The Princess wrote on the 12-23 February, 1783, asking him to correspond with the Academy. “ Nobody better than you, whose abilities are known in all Europe, could add a lustre to it.” In his answer Black took some time ; the reply is dated 4th September ! The diploma arrived through Dr. John Grieve, by way of Riga, in June.

About the same time M. Amelot, the *Sécrétaire perpétuel*, tells him that he has been elected *Associé Étranger* de la *Société Royale de Médecine de France*, and Black thanks the Academy through him in cordial terms, of course again in French.

In a letter from Mr. Macculloh, member of the Hon. the Board of Trustees for Manufactures, we see an early effort to provide technical instruction for young operatives. He proposes “ to improve manufactures by establishing a Bleach field for the purpose of an Academy in some central place the most contiguous to where the low-price Linen Manufacture is carried on, where every person presented by the Board should be taught the making of a refined Lee from burnt crude ashes, for at least one whole season. Believing that the Doctor will agree with them that the illiterate vulgar can only be taught by practical demonstration, but by no means by either verbal lecture or written precept.” Black’s reply is not preserved.

About this time two long pieces of correspondence, one on the rusting of iron bolts in ships, and the other on brewing and fermentation, took place. In Black's contribution to the first he "does not admit that the water received from the copper sheathing can have any disposition to corrode the iron"; he thinks it must have resulted from the "juices from the wood." He does not appear to have made any experiments on the corrosive action of sea-water on iron in contact with copper, but to have given a judgment according to the dictates of his inner consciousness.

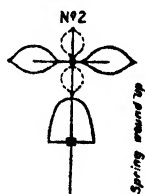
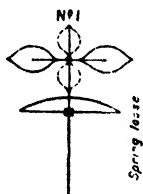
The next letter, from Mr. Daly, to whom Black wrote, asking him to make inquiries as to the cost of lodgings and tuition for his nephew, aged 15, throws light on the manners of the time. It appears the young gentleman was to be accompanied by his body-servant, and was to board with a curate, from whom he would receive instruction. Mr. Daly replied: "It is much more difficult than I expected. The first enquiry I made was of a curate within 4 miles of here (Leyland). He seemed unwilling to take such a lodger into his house; as he told me, he expected the servant would make free with his maid. But I suspected he was in greater concern for his pretty wife. Still he told me, on my assuring him that the servant could behave very soberly, that he would take him at £50." Mr. Daly went to no fewer than eight curates, each of whom raised the same objection; moreover, no one would take less than £50 a year to lodge and board the youth and his servant, and to give lessons to the former. He next tried the laity, and "rode 14 miles

to the house of a gent. named Woodcock ; he is a man of 5 or 6 hundred pounds a year, and can give excellent accommodation. Master Black could ride one of his horses, or take an airing in his chair twice a week. But his price is very high ; not less than 50 gs., without washing for him or his servant." Mr. Daly then " addressed himself to the tenderness of a lady friend " ; he found that part " most assailable," and induced her to promise to take the boy in for £40 a year. For that, " he could have an excellent apartment to himself, & see as genteel company as any in this part of the country." The boy was sent there ; but there is no record of his subsequent career. Before sending him, however, Black wrote to Mr. Richard Kentish, who recommended Catterick Academy, Bridlington, about forty miles from York, kept by Mr. John Kirkley. The fees were: Entrance, £1 1s. ; board, £14 14s. ; education, including French, £2 2s. ; washing, £1 6s. ; repairs, 8s. ; in all £19 11s. The man can board for £10 a year, provided he lives with the family. One is reminded of Do-the-Boys Hall ; it must have been difficult to keep a school on such terms and to support a family.

On 23rd June, 1783, Black was elected an " ordinary member " of the Royal Society of Edinburgh ; in that year the Philosophical Society, which was founded about the year 1739, was dissolved, and incorporated as the Royal Society of Edinburgh by Royal charter. The notice of his election is signed by John Robison, his biographer and the editor of his lectures.

In May, 1784, Dr. John Grieve wrote from Paris :

“ With respect to the air-balloons, which are now scarcely even mentioned in Paris, there is an account in the last *Mercur de France* of a method of conducting them in all different directions, and even against the wind. The experiment is said to have been made in presence of Mongolfier, who, with several others, subscribed to the truth of it. The inventor is of Lyons, and it was there the trial of it was made ; his name is Marcié.” In October Grieve recurs to this matter : “ Before I left Paris, there was one Bienvenu, who showed a flying-machine, without any reference to the balloon, but which, I think, might be applied to the direction of these. It consisted of four wings, like so many inverted kites, fixed to an axis, at angles of about 45 degrees. These were found, on the circular motion of the axis, to act on the air like the perpetual screw of Archimedes, and that in any direction. To exemplify this, he had a spring like a bow tied to the lower end of the axis, the string of which, being fixed to a circular piece of wood upon the axis, resembling a pulley, and being wound up on this, was no sooner let go than the two ends of the bow receding from each other turned round the axis, and with it the wings. In this manner, the machine flew the height of about ten feet. I have enclosed a very rude sketch of it.”



The next letter which Black received on aerostation was in October, 1784, from James Lind, Windsor ; it is as follows : " My friend Mr. Cavallo is now at work compiling a history of Aerostation, and as I believe you was the first person that attempted to make a body rise in air by means of Inflammable gas, you will oblige me much by informing me of the particulars and the date of that transaction. To the best of my remembrance, it was in the year 1767, and Dr. Hutton assisted in the experiment. I likewise beg to know who was the person that first discovered the true specific gravity of Inflammable air. You will, I make no doubt, have had an account of Dr. Priestley's improvement on Mr. Lavoisier's process for obtaining Inflammable air by means of Steam and heated Iron. Mr. James Watt sent me a very particular account of that curious process, which strongly confirms the truth of his hypothesis on the constituent parts of water. I beg my best compliments to Dr. Hutton."

To this Black replied : " It gave me no small pleasure to receive a letter from you after so long an interruption of our correspondence, and I can readily answer the questions you put to me. The person who first discovered with exactness the specific gravity of inflammable air was Mr. Cavendish. I never heard of any experiments made with that intention before his appeared in the Philosophical Transactions for the year 1766. It had been my constant practice before, to shew every year in what manner it burns when it is pure or unmixed with air, and in what manner it explodes when air is mixed with it

before it is fired ; but Mr. Cavendish made a variety of such mixtures by rule and measure, and describes in the same paper the manner in which they severally explode. As soon as I read the above paper, it occurred to me as an obvious consequence of Mr. Cavendish's discovery that if a sufficiently thin and light bladder were filled with inflammable air, the bladder and contained air would necessarily form a mass lighter than atmospheric air, and which would rise in it. This I mentioned to some of my friends, and in my lectures the next time I had occasion to speak of inflammable air, and of Mr. Cavendish's discoveries, which was either in 1767 or 1768. I thought it would be an amusing experiment for the student ; I applied to Dr. Munro's Dissector to prepare for me the allantois of a calf. The allantois was prepared, but not untill some time when I was engaged with another part of my course, and did not chuse to interrupt the business then going on, so I dropped the experiment for that year, and in some of the subsequent years I only mentioned it as an obvious and selfevident consequence of Mr. Cavendish's discovery, but never made the experiment, which I considered as merely amusing. I have heard in general that Dr. Priestley has obtained a cheap process for preparing inflammable air, but have not learned any particulars of it, & if you have a little spare time, it will be doing me a great favour to communicate a short account of it."

Dr. Lind replied in November, giving an account of Priestley's process for making inflammable air, taken from the account " which Mr. Watt was so obliging as

to send me for His Majesty." He describes how Mr. Lavoisier found that steam, passed through an empty iron gun-barrel, gave some inflammable air. He imagined that this would not be the case had the steam been passed through a tube of heated copper ; but he could not get a copper tube made without solder in Paris to try the experiment. Mr. Watt prompted Dr. Priestley to try it, and furnished him with the necessary apparatus for the purpose. (Here follows a description of the apparatus, which is quite on modern lines.) " As Mr. Lavoisier imagined, no change was produced on the steam of water passing through the heated tube, but on filling it with turnings of heated iron, 30 ounces measure of inflammable air was produced in 50 seconds, and an ounce of iron yielded in this way 600 ounces measure of inflammable air, which is a half more than it yields with vitriolic acid ; the residuum in the tube was similar to scales of iron. Mr. Watt thinks 10 tubes of cast iron, with 6 feet of each tube heated, of 2 or 3 inches diameter, filled with turnings of hammered iron, might produce as much inflammable air in 12 hours as would fill a balloon of 30 feet in diameter." " If you should come to this part of the world, believe me I shall be happy to see you at Windsor ; besides the beauties of this place, the Royal Family here is HERSCHEL."

Black answered this letter : " As you speak of the *birth* of aerostatic experiments, I beg leave to communicate to you more fully my thoughts on that subject. In the first place, although what I have already informed you of is strictly true, I by no means set up my claim for

merit in the invention of machines for general flights & excursions. The experiment with the bladder, which I proposed as a striking example of Mr. Cavendish's discovery, was so very obvious that any person might have thought of it; but I certainly never thought of making large artificial bladders, and making these lift heavy weights, and carry men up into the air. I have not the least suspicion that this was thought of anywhere before we began to hear of its being attempted in France, and I do not doubt that what has been published in the newspapers is perfectly true, viz. that Mon^s Mongolfier had sometime before conceived the idea of flying up into the air by means of a very large bag or balloon of common air, simply rarified by the application of Fire or Flame.

“The idea being founded upon a principle which has long been known, and which has no connection with Mr. Cavendish's discovery, it is only surprising that Mon^s Mongolfier should not have put it sooner in practice. I suppose therefore that though he might have formed the Project a long time before, he never was roused into an operation for making the trial until others began to think of flying by means of Inflammable Air. Who first thought of the method I cannot tell, for I confess I did not read the history of these Experiments; they never interested me in the least. The hope that means might be discovered for moving these machines at pleasure and directing their course could only be formed by those who did not consider and understand their nature. The only circumstance which enables them to subsist in the air, however brisk the wind may be, is that, as

soon as they rise, they are in effect perfectly becalmed ; I mean that there is not the least perceptible motion or impulse of the air against any part of them ; this is perfectly evident from their situation. They float in mid air, and have no hold on anything else ; the air must therefore carry them along with a velocity equal to its own. The machine of itself can make no resistance, but while it moves along with the air, it cannot feel any motion of the air against it in any direction. It must therefore be in effect a dead calm ; the motion of it cannot be perceived by those who are carried by it, except from the apparent motion of the objects on the surface of the earth, which seem to slide away from them ; this tranquillity of the air with respect to them is one circumstance which contributes to that composure of mind which many of those feel who mount with balloons. I can imagine, however, that in a hot climate, when the weather is perfectly calm and the sun shining bright, a large balloon ascending with considerable velocity may occasion a whirlwind and be involved in it, which may be attended with dangerous consequences to those who accompany it. And this among other things shews the folly of attempting to give it motion at pleasure, or to command its motion or direction when it is up in the air ; for besides the impracticability of finding a power that can be applied to produce this effect, although the power were found, any attempt to make use of it would destroy the balloon by impelling it against the air, and exposing it to such shocks and violence as it cannot bear ; and further, in attempting to use such a power, it must

necessarily happen, on account of the great surface of the balloon, & the resistance the air would make to its motion thro it, that the men and machinery by which it were moved must necessarily go foremost, and the large bladder, &c. would be dragged after them in a horizontal direction, which would require an apparatus totally different from what has already been contrived."

Black was no true prophet; the airship of to-day, made possible by the internal-combustion engine, is no doubt an apparatus totally different from what he conceived; the risks it runs are not due to the engine running away from the balloon.

In his account of the part he played in suggesting hydrogen as a means of raising a balloon, he scarcely did himself justice; Thomas Thomson, his follower in the Glasgow chair in 1818, in his History of Chemistry, tells the following tale: "There is an anecdote of Black which I was told by Mr. Benjamin Bell, of Edinburgh, author of a well-known system of surgery, and he assured me that he had it from the late Sir George Clarke of Pennicuik, who was a witness of the circumstance narrated. Soon after the appearance of Mr. Cavendish's paper on hydrogen gas, in which he made an approximation to the specific gravity of that body, showing that it was at least ten times lighter than atmospheric air, Dr. Black invited a party of his friends to supper, informing them that he had a curiosity to show them. Dr. Hutton, Mr. Clarke of Elden, and Sir George Clarke of Pennicuik were of the number. When the company invited had assembled, he took them into a room. He had the

allantois of a calf filled with hydrogen gas, and upon setting it at liberty, it immediately ascended and adhered to the ceiling. The phenomenon was easily accounted for : it was taken for granted that a small black thread had been attached to the allantois, that this thread passed through the ceiling, and that some one in the apartment above, by pulling the thread, elevated it to the ceiling, and kept it in this position. This explanation was so probable, that it was acceded to by the whole company ; though, like many other plausible theories, it turned out wholly unfounded ; for when the allantois was brought down, no thread was found attached to it. Dr. Black explained the cause of the ascent to his admiring friends ; but such was his carelessness of his own reputation, and of the information of the public, that he never gave the least account of this curious experiment even to his class ; and more than twelve years elapsed before this obvious property of hydrogen gas was applied to the elevation of air-balloons by M. Charles, in Paris."

These gentlemen, no doubt, told all their friends ; and the fact that a hydrogen balloon would ascend became known ; so that in spite of Black's disclaimer, he must be recognised as the first to suggest the possibility of applying hydrogen to this purpose.

The inhabitants of Edinburgh had not long to wait before seeing the practical application of Black's small experiment ; for on October 5th, 1785, the aeronaut Vincent Lunardi visited Edinburgh and made an ascent from Heriot's Hospital Green, in a balloon filled with hydrogen, in the presence of 80,000 spectators. Attempts

had previously been made in Edinburgh by Mr. Tytler with partial success. The height reached by Lunardi was about three miles ; he descended not far from where he began his ascent, having been fortunate in weather and in the direction of the wind.

We must return to Dr. Grieve's letter from Paris ; it touches another interesting topic : Mesmer's practice. " But what of all other forms the most frequent subject of conversation here at present is the *Magnetisme Animal*, as it is called, of one Mesmer, a German Physician. The substance of it is that there is a subtile fluid which fills the Universe, which forms a connecting medium between us and the heavenly bodies, and between us and the earth. He says that he has discovered means by which he can direct the course of this fluid, accumulate it in our body, and convey it to another at pleasure. He ascribes many diseases to the unequal distribution of it, and offers to cure many by restoring the equilibrium. The system, singular as it is, has more friends than enemies ; his house is so much crowded that there are seldom fewer than two hundred people in it at one time, and that in succession from morning to night, all of whom undergo his operations. When you are told that he has five guineas the first month, and four every subsequent one from each patient, and that he has already sold his secret to a hundred and fifty persons for a hundred guineas each, you will judge what an immense fortune he is likely to make in a short time. I was in his house the other day and was witness to his method of operating. In the middle of the room is placed a vessel of about a foot and

a half high, which is called here a *bacquet*. It is so large that twenty people can easily sit round it ; near the edge of the lid which covers it, there are holes pierced corresponding to the number of persons who are to surround it ; into these holes are introduced iron rods, bent at right-angles outwards, and of different heights, so as to answer to the part of the body to which they are to be applied. Besides these rods, there is a rope which communicates between the *bacquet* and one of the patients, and from him it is carried to another, and so on the whole round. The most sensible effects are produced on the approach of Mesmer, who is said to convey the fluid by certain motions of his hands or eyes, without touching the person. I have talked with several who have witnessed these effects, who have convulsions occasioned and removed by a movement of the hand. In order to qualify this account, which will appear incredible, if not ridiculous, I shall add the answer of M^r Le Roi, the Academician, to my question ‘ What he thought of it ? ’ He has been appointed one of the Commissioners to examine into the operations of one Deslon who is a scholar of Mesmer. His words were these — ‘ Je n’en puis pas encore juger ; mais j’ai déjà vu des choses très singulières. ’ ”

At this date, the recent experiments of Cavendish and Watt on the formation of water by the combustion of hydrogen were being vehemently discussed through the whole chemical world. Grieve, in this letter, says : “ The chemical experiments made by Lavoisier and Meunier on water, & the conclusion drawn from them,

viz. that water is composed of dephlogisticated and inflammable air (oxygen and hydrogen), does not meet with general credit in this place." It was some years later before they were accepted.

In October Grieve wrote again: "Since my last letter, I had frequent opportunities of seeing Mr Lavoisier, and of visiting him at his house. It gave me much pleasure to hear the honourable mention he made publicly of your name, acknowledging you, in presence of several Academicians, as the author of all these discoveries in Chemistry which have of late years made so happy a revolution in that science.

"As Mr Argand, the inventor of the new lamps, is come to London, and is joined with Mr Parker, the Glass Manufacturer, in a patent for them, you will soon know them. Their principle is simple, and their effect highly advantageous; by placing the wick in a circular form round a hollow cylinder, and thereby establishing a current of air from below to the inside of the flame. This increases the light in the proportion of 10 to 1, and as the heat is equally augmented, the smoke is totally consumed. Mr Argand is a native of Geneva."

It may be a matter of surprise that Black was not stimulated, by hearing of the rapid progress which was being made, into himself sharing in the work. Robison explains the reason. "But alas! his lot forbade. His constitution had always been exceedingly delicate. The slightest cold, the most trifling approach to repletion, immediately affected his breast, occasioned feverishness, and if continued for two or three days brought on a

spitting of blood. In this situation, nothing restored him to ease but relaxation of thought and gentle exercise. The sedentary life to which study confined him was manifestly hurtful, and he never allowed himself to indulge in any intense thinking, or puzzling research, without finding these complaints sensibly increased.

“ Thus situated, Dr. Black was obliged to be contented as the spectator of the successful attempts of others.”

Black's friends were afraid that sufficient credit might not be given to him for his work ; and at one time he began the task of putting on paper an account of the part he had played in the development of the science of chemistry. Although Lavoisier had given proofs of the great esteem in which he held Black, as reported by Dr. Grieve, Black was annoyed by the scant notice bestowed on his work in Lavoisier's published papers, and considered his expressions of good-will to be insincere.

For long Black took no part in the controversy which led ultimately to the abandonment of the phlogistic theory ; indeed, very few allusions to it occur in his correspondence. A letter to him from Dr. Eason, of Manchester, in September, 1787, makes the remark : “ Doc^r Priestley, not having any one to steal from at present, I believe is quiet, unless it is to trouble the world with his religious nonsense.” In November of that year Dr. Beddoes, the promoter of the inhalation of gases, and the early patron of Sir Humphry Davy, wrote to Black saying that he was thinking of publishing a new

arrangement of the subjects dealt with under the name of Chemistry. To this letter Black replied :—

“ I had the pleasure to receive your letter of the 6th current, and very much approve of your trying to plan a new arrangement and classification of the objects of chemistry. There is no doubt that many of the substances which not long since were considered as simple are now viewed in a very different light from that in which they formerly appeared. As you have been on the spot where those improvements have been most ardently promoted and discussed, and as you are otherwise very well prepared for such an attempt, I am happy to hear that you think of engaging in it, and have no objection against your addressing it to me, but on the contrary shall think it an honour ; tho at the same time I beg you will consider yourself as at full liberty to change your mind with respect to this point, and give your work, when finished, any other form or titule that may suit better. I have not yet seen the *Nouvelle Nomenclature*, but have commissioned a copy.” “ Were it in my power to promote your undertaking by entering immediately into the consideration and discussion of the subject, I should be very happy to do it ; but I confess I find it at present impossible ; while my course is going on, my time is so much filled up, & I am hurried so much from one subject to another, that I can seldom sit down to study new things. I assure you that it will cost me much study before I could attempt to think of a new arrangement like that you propose. Can you give me any new information concerning Dr. Fordyce’s experiments



BLACK LECTURING.

From Kay's portraits.

on the weight of cold and hot bodies, or on that of ice & of water? The experiments, I know, have been repeated in France, & I believe the result has been various. I shall be happy to hear from you when you have time."

In February, 1788, Dr. Beddoes wrote again; he was then at Oxford, and says that he has "the largest class in chemistry that has ever been seen at Oxford within the memory of man, in any department of knowledge, although my number cannot be put in competition with those in Edinburgh. What I find most difficult is to repeat some of those simple experiments, which in your hands are so striking and so instructive. How do you contrive to make that experiment which shows the burning of iron in dephlogisticated air? . . . Of the chemical news that I have last heard, the most important is that Dr. Priestley, in repeating Mr. Lavoisier's experiments with airs as dry as possible, gets an acid from the combination of the solid basis of dephlogisticated with that of inflammable air. Dr. Withering has had the acid to examine, but has not found out what it is. It is not the nitrous, or seems not to be it."

This subject is also alluded to in a letter from James Watt, written in June, 1788. "I have nothing else new in the philosophical way, except repetitions by Dr. P. of his experiments on the deflagration of D^a and $infl^e$ airs, in which nitrous acid is always produced. As the deflagrations were performed in copper vessels, the acid is saturated with copper and is green, but becomes blue on the addition of a small quantity of common spirit of

nitre. It appears, however, that more than 9-10ths of the liquor thus produced is water, which probably in its own form constitutes the greater part of the mass of all sorts of air. I think it highly probable that the acid proceeds from the inflammable air, and that the D^d air acts the same part that it does in the burning of sulphur and phosphorus.

“ I remain, Dear Doctor,

“ Yours affectionately,

“ JAMES WATT.”

This letter of Watt's shows clearly the difference of the two points of view of the new and the old school. While Lavoisier and his followers advanced the view which is now universally accepted, namely, that hydrogen and oxygen, when exploded together, combine to form water, and nothing else, Watt was inclined to believe that the water was present in a concealed state in all gases, hydrogen and oxygen among others ; and that it was thrown out by the act of combination, and was not the product of the combination. Priestley's observation of the formation of nitric acid was due to his having used impure gases, contaminated with air, and consequently containing nitrogen ; on explosion some of the nitrogen united with the oxygen and the water, forming a small amount of nitric acid. Watt appears to conjecture that this nitric acid is the real product of the combination of the hydrogen and the oxygen, and is the result of the oxidation of the hydrogen, just as sulphuric acid is produced by the oxidation of sulphur, and phosphoric

acid, of phosphorus. It was Cavendish who proved that if the hydrogen and oxygen are pure, no nitric acid is formed.

During October, 1788, Black visited Watt at Birmingham, and also stayed with the Dean of Christchurch at Oxford. As regards the Dean, Black wrote: "I do not know what health he commonly enjoys, but *entre nous*, he had the appearance of a person who slept too warm, or in too soft a bed, which is very relaxing. I sleep at home upon two mattresses, and I have had much better sleep since I came home than when in England."

In March, 1789, Dr. Hope, Lecturer on Chemistry at Glasgow, who had succeeded Dr. Irvine in 1787, wrote to Black: "I am sorry that I am not able to give you any satisfaction respecting the thoughts entertained by the French chemists concerning Dr. Priestley's experiments on the deflagration of pure and inflammable air in the driest state possible. I have heard them spoken of but once or twice. Before the Doctor's paper itself reached Paris, an imperfect account of it had elevated much the hopes of the phlogistians, and excited a little the alarms of the anti-phlogistians. A perusal, however, very easily caused both to cease. It is true that a very poor translation of the Doctor's paper had been made in the absence of La Matherie, and had been inserted into the *Journal de Physique*, which might not have had so much weight as a better one probably would have had. I found that it was imagined that the Doctor's experiments in which $1\frac{1}{2}$ grain of water was obtained, instead of 4 grains, would little avail to shake the belief of those who had conducted their experiments on so grand a scale

that they procured many ounces weight of pure water, which exactly equalled the weights of airs which had been used.

" The appearance of nitrous acid was not deemed more conclusive, as none had ever occurred in the experiments in which the airs united by a gradual inflammation ; and as Mr. Cavendish, in his paper on water, and nitric acid, had remarked its occasional occurrence, and had indicated the source from which it proceeded.

" Such were the sentiments of those I heard speaking on the subject ; and very similar ones, I must confess, did the reading of Dr. Priestley's papers call up into my mind. But as the composition of water unquestionably is the cardinal point of the antiphlogistic system, to which I profess myself very strongly inclined, and as there exists no person in whose opinion I would rely personally with such implicit confidence as on yours, since to you I owe any little chemical knowledge I may be possessed of, I hope you will excuse the freedom I use in expressing how glad I should be to know the sentiments you have formed on these experiments, and will pardon my thinking of troubling you so much as to request to be informed whether you imagine Dr. P.'s observations are sufficient to controvert or even to create a well grounded suspicion concerning the accuracy of those of Cavendish and Lavoisier, Monge, Meusnier, &c. &c. I must conclude by assuring you of the very perfect respect with which

" I remain Your really obliged servant,

" THOS. CHAS. HOPE."

" GLASGOW, March 22nd, 1789."

In April, 1789, Dr. Beddoes wrote · “ Dr. Priestley seems totally to have overthrown the antiphlogistic theory. I am anxious to hear what the French chemists have to say on the other side. I have seen some of their private objections to Dr. Priestley’s inferences, but they seem totally insignificant. Still, however, we owe much to Mr. Lavoisier for having taught us the combinations of pure air.”

There is no record of an answer to this letter. But in 1791 Black thought it necessary to declare his adhesion to the new doctrines, for there appeared in the *Annales de Chimie*, p. 225, a “ Copie d’une lettre de M. Joseph Black à M. Lavoisier,” from which the following sentence may be quoted :—

“ Ayant été habitué trente ans à croire et à enseigner la doctrine du phlogistique comme on l’entendoit avant la découverte de votre système, j’ai longtemps éprouvé un grand éloignement pour le nouveau système, qui presentoit comme une erreur ce que j’avois regardé comme une saine doctrine ; cependant, cet éloignement qui ne provenoit que du pouvoir de l’habitude seule, a diminué graduellement, vaincu par la clarté de vos démonstrations, et la solidité de votre plan.” . . . “ Je souhaite une heureuse fin à la révolution de votre pays, et suis avec la plus haute estime, &c. JOSEPH BLACK.”

Robison gives a detailed account of the relations between Black and Lavoisier at this time, and of how this letter came to be written. It appears that shortly after Black had been made an “ Associé étranger ” of the French Academy, the Marquis de Condorcet, on his

return to Paris after a visit to Edinburgh, informed Lavoisier that Black was in the habit of using the new system in his lectures ; whereupon Lavoisier wrote to Black the following letter : “ J'apprends avec une joie inexprimable que vous voulez bien attacher quelque mérite aux idées que j'ai professé le premier contre la doctrine du phlogistique. Plus constant dans vos idées que dans les miennes propres, accoutumé à vous regarder comme mon maître, j'étais en défiance contre moi-même tant que je suis écarté, sans votre aveu, de la route que vous avez si glorieusement suivie. Votre approbation, Monsieur, dissipe mes inquiétudes, et me donne un nouveau courage. Je ne serai content jusqu'à ce que les circonstances me permettent de vous aller porter moi-même le témoignage de mon admiration, et de me ranger au nombre de vos disciples. La révolution qui s'opère en France devant naturellement rendre inutile une partie de ceux attachés à l'ancienne administration, il est possible que je jouisse du plaisir de la liberté, et le premier usage que j'en ferai sera de voyager, et surtout en Angleterre, et à Edimbourg, pour vous y voir, pour vous entendre, et profiter de vos leçons et de vos conseils.”

Robison then goes on to say : “ Dr. Black wrote him a very plain, candid, and unadorned letter in answer, expressing his acquiescence in his system. Mr. Lavoisier answers this by praising in the highest terms the elegance of the style, the profoundness of the philosophy, &c., &c., and begs leave to insert the letter in the *Annales de Chimie*. Dr. Black, who had been in very poor spirits

when he wrote that letter, and was much dissatisfied with its feebleness, was disgusted with what he now conceived to be artful flattery, and refused to grant the request. Yet his letter appeared in that work before his refusal could reach Paris.

“ This wheedling, in order to screw out of Dr. Black an acquiescence, on which he put a high value for the influence it would have on the minds of others, was surely unworthy of Lavoisier. Dr. Black was not only disgusted with the flattery, but seriously offended with its insincerity ; and with a sort of insult on his common sense, by the supposition that he could be so wheedled, by a man whose publications never expressed the smallest deference for his opinions. For, by this time, Dr. Black had read Mr. Lavoisier's *Elements of Chemistry*, and the various dissertations by him and Mr. De la Place, published in the *Memoirs of the Academy*. His name is not once mentioned, even in the dissertations on the measures of heat, where his doctrine of latent heat is delivered and employed as the result of Mr. Lavoisier's own meditations. Nor is he named in those passages of the earlier dissertations, where the characters and properties of fixed air and of the mild and caustic alkalies are treated of. All appears to be the train of Mr. Lavoisier's own thoughts, for which he was indebted to no man. Such inconsistency with the deference expressed in the above-cited letters provoked Dr. Black to such a degree, that he resumed his critiques on the nomenclature, and began to express his dissatisfaction with some parts of the theory, and his utter disapprobation of the unscientific and bullying

manner in which the French chemists were trying to force their system on the world. But by this time, his health was become so delicate, that the least intensity of study not only fatigued him, but made him seriously ill, and forced him to give it up. I saw him but seldom at this time, being then in very bad health myself; but had this information from Dr. Hutton, who shared all his thoughts. It was at this time that he gave up his intention of making a considerable change in the arrangement of his lectures, and that he expressed himself, as I have related, at the end of the introduction to the particular doctrines of chemistry. But still, notwithstanding the contempt which he expressed for the folly of a man who had tried, by fulsome and insincere flattery, to obtain what he had given him unasked, by teaching all his doctrines, Dr. Black considered the death of Lavoisier as a great loss to the science. He expected much from his penetration and sound sense; and he considered him as the only person who could keep his followers right, by checking their precipitate manner of proceeding."

It appears to me that credit should be given to Lavoisier for sincerity in what he wrote to Black. An emotional Frenchman will express feelings perfectly genuine at the moment, yet inconsistent with his other actions. It is however, not to be wondered at that Black, a calm, deliberate Scotsman, who never acted on impulse, should have failed to understand the mentality of Lavoisier. There is no doubt that Lavoisier was much to blame, not only in his omission to acknowledge what he owed to

Black, but also to Priestley and Cavendish. His deservedly high reputation would have stood even higher, had he given credit to others for bringing to his notice the facts on which his theories were based.

Thus Black definitely abandoned phlogistic doctrines. The only other allusion to it in his correspondence is in a letter received from Dr. Menish, of Chelmsford, in Essex, in December of that year, and its answer ; they are as follows :—

“Great have been the discoveries and great the revolutions in chemical theories since I last had the honour of receiving your instruction in these subjects. 'Tis with particular pleasure I have seen your theory of latent heat received everywhere, and made the foundation for new theories. In my time, water was supposed to be convertible into earth ; at present, 'tis the received opinion that it is resolvable into two species of air. The experiments of producing these different airs from water by means of the electric spark is a very capital discovery, and of great importance. Light and heat and all fluids, we know, are capable of entering into combination with bodies ; why should the electric fluid be excluded from having this property ? and of contributing its share in the formation of the two airs from water ? ”

To this Black replied : “ Your theory of fire and electricity, and of the nature of the hydrogenous and oxygenous gas is very ingenious & worthy of being further considered, & subjected, if possible, to experimental investigation. For my part I now, tho I had a reluctance at first, find the French theory so easy and applicable that

I mostly make use of it, tho it must be confessed that it takes almost no notice of light."

Seven years earlier Cavendish had stated very clearly the two theories ; he believed them to be equally suitable to express the knowledge of the time ; but he decided to retain the older methods of expression as being more readily understood. Almost every other chemist followed Black's example, and decided in favour of the new theories ; the exception was Priestley, who resisted to the last ; one of his latest publications was an attempt to defend the old views. There is no doubt that Black's pronouncement did much to ensure the acceptance of Lavoisier's doctrines in Great Britain ; his friend Beddoes wrote in April, 1791 : " I am glad to see your renunciation of the old Chemical Theory in the *Annales de Chymie*."

CHAPTER VI

WE may now turn to some of Black's analytical and technical investigations.

In 1784 Watt asked Black to look into the composition of a sample of water which corroded a piston-rod belonging to a Mr. George Meason. His report is : The water reddened litmus, and had a "fadeish" taste. On leaving it to stand in a glass, small air-bubbles adhered to the walls. Twelve ounces of it, treated with 10 grains weight of lime-water, lost its power to redden blue litmus. A wine-glass full of water from the cistern became more white or muddy with "sacch. Saturni" solution (lead acetate) than the sample. It became very slightly muddy with $\frac{2}{3}$ of D (silver nitrate), and would not clear with O (nitric acid). The corrosion of the piston-rod was afterwards discovered to be due to the acidity of the oil or tallow used as a lubricant ; and the admixture of a little soap with it made it alkaline, and stopped the corrosion.

Black made reports in July and September, 1784, on water from the water of Leith, a small river running through what is now the northern part of Edinburgh ; and also on water from Salisbury Crags, an escarpment

of Arthur's Seat, whence it issued in a spring. His report was :—

“No. 1 was clear to the Eye. To the taste, it was sweet and good water. In dissolving soap, it was rather softer than Edinburgh pipe-water. 7000 grains weight of it left on evapn. only $\frac{3}{4}$ grain of solid matter, which was saline and earthy. Edinburgh pipe-water contains $1\frac{1}{2}$ grains of this matter in 7000 grains of the water. A considerable part of this matter is chalk or lime.”

Black and Robison were asked by the Commissioners of Police for Leith whether they recommended Salisbury Rock water, or Lochend water to be brought into Leith in pipes ; but there is no record of their advice. It is interesting, however, to see how a water-analysis was carried out in 1784.

In May, 1787, Lord Elcho consulted Black about a mineral water supposed to be ferruginous, and asked him how it compared with that of Tunbridge. Black was unable to compare them, for he did not know the composition of Tunbridge springs ; he recommends, however, a very effective plan of collecting such water without exposure to air.

From then on Black's time must have been greatly occupied with consulting work, for there is much correspondence with inventors and business men. Some of his work is interesting, and may here be shortly described.

In October, 1784, Mr. Robert Murray, of Manchester Square, London, consulted Black on an improved method of making sugar ; he enclosed a long letter in French,

dealing with the boiling-down of the juice ; Black recommends that a flat pan should be used, of which the outer portions should be protected from the flame by brickwork, so that it should strike only the middle of the pan. In December, 1785, he replied to C. Gascoigne, who consulted him as to the best method of making an " essay " of pig-iron. It should be mixed with one-quarter of its weight of calx of iron (oxide), prepared by igniting the precipitate obtained by adding pearl-ashes (potassium carbonate) to copperas (ferrous sulphate). The mixture is heated in a small crucible to the highest attainable temperature ; the button which is formed should be tested as regards its malleability.

Black has left notes dealing with his method of testing limestone ; he dissolves it in V^c (hydrochloric or acetic ?), noting the quantity of acid used. He then ignites a sample until the weight is constant, and weighs the residue. A sample is also treated with acid, and the insoluble residue is weighed, and examined by colour and general appearance, with the view of determining whether it contains iron or consists of clay.

In February, 1787, Mr. Cort writes from Gosport about the iron he manufactures ; he wishes he could procure more powerful hammers, so as to consolidate the bars better for making large objects, such as anchors for the Navy. To this letter Black replies politely, but makes no recommendation. He suggests that the speckled appearance of Cort's iron may serve as a criterion of its excellence. There appears to have been competition between Cort and the Swedish manufacturers ; trials

were made in the Royal Dockyards, the flukes of the rival anchors having been bent by men pulling chains attached to them by means of tackle. It appears that at that date 20,000 tons of Swedish iron were imported from Sweden and about 50,000 tons from Russia. The quantity of iron made in Great Britain was 85,000 tons a year, produced from eighty-five blast-furnaces. Cort rolled his bars; he did not forge them. The rollers were rotated by one of Boulton and Watt's steam-engines; hence his application to Black for advice.

Mr. John Roebuck, of Bo'ness, consulted Black about glaze for pottery. In the reply, after instruction to use white lead instead of red lead, and to add borax as a flux, he goes on: "I am doubtful if manganese or arsenic be necessary or useful in the composition of glazings, & the last is so very dangerous to the health of the poor workmen that it cannot be used tho ever so cautiously without constant apprehensions of its doing mischief." He then describes the preparation of gold for gilding: dissolving gold in aqua regia, evaporating the solution to dryness, and igniting; or precipitating with sal martis (ferrous sulphate). In either case the gold is mixed with borax and oil of lavender to give it the consistence of a paint. Black then goes on to describe the best method of preparing a brightly coloured "Purple of Cassius."

In November, 1788, the Trustees of Invention in Scotland asked Black to report on a new blast, invented by Joseph Baader, of Munich, who requested them to supply him with money to develop his invention. The

smallest size, he says, is applicable to a smith's forge, and would cost £1 10s. or £2, instead of the usual £5 or £6. On Black's advice the trustees sanctioned the expenditure on a blower for a smith's forge before committing themselves further. I have not been able to ascertain whether the Trustees of Invention were supported by public funds or were a private body ; but they must evidently have filled a useful purpose. Indeed, one is struck with frequent references to societies which existed in order to encourage invention and discovery ; some of these might with advantage be revived.

Bound in with his letters are a lot of samples of tape, dyed in various shades of blue and labelled, " the first experiments I made to compare indigos." There is no further record of such experiments.

In 1789 Black became financially interested in a process for making alkali. In July of that year he received an " Estimate for a factory for marine alkali from Mr. Birnie at Glasgow (Head of Gallowgate)." Birnie states that the cost of lead from ore, including wages, coals, etc., would be £59 15s. per ton. The lead was to be made into " calx " (oxide) and ground, mixed with salt (at £6 a ton, including duty), costing with labour, coal, etc., £26 12s. ; the sum is £86 7s. The sale of the silver from the lead at 5s. 9d. an ounce would bring in £60 7s. 6d. ; and there were produced four tons of mineral alkali, selling at £23 a ton, together making £152 7s. 6d. ; deducting the cost, £86 7s., there is a weekly profit of £66 os. 6d. Black replied, asking : " In what manner is the alkali to be aerated ? " He adds : " Try whether the salt will be

the better of a slight calcination, or rather of a red heat before it is dissolved in water, and mixed with the calcined lead ; the effect of the red heat will be to decompose the Magnesia muriate, & purify the salt. Thus the *Calx plumbi* will be employed to better advantage." He also enclosed a letter of introduction for Mr. Birnie to Dr. Hope, of Glasgow ; Mr. Birnie has some beautiful specimens of red lead to give him.

In September, 1789, Black wrote to Mr. Ronald Crawford, of Glasgow, saying that Mr. Birnie had told him that he had received very friendly treatment from Mr. Crawford. "I take the liberty to begin in this manner a correspondence with you on the subject of his intended manufactory, in which I propose also to be concerned. When Mr. Birnie first spoke to me (although this is a sort of manufacture which I have long wished to see established) I had no desire to have any share in the undertaking, being habitually very diffident of all new projects, on account of the time, expence & trouble they generally require at first to bring them to a state of perfection. I changed my mind, however, & am now disposed to pursue the object with zeal until we shall be satisfied with respect to its value."

The next allusion to this manufacture occurs in February, 1790 ; Black received a letter from Mr. W. Fullarton, saying that he had had an application from the Duke of Orleans, who was desirous to know the most expeditious and least expensive means of decomposing marine salt (or, as he calls it, "sel de cuisine") and of extracting from it the mineral alkali, or "sel de soude."

A gentleman of "chymical" knowledge in His Highness's household had told him that the means of obtaining the mineral alkali pure was understood in this country. It will be remembered that in 1789 Leblanc had submitted his plans to the Duke of Orleans and had received financial support; and that in 1791 Leblanc's process was patented. Evidently the Duke was making inquiries, so as to find out whether the process he was supporting was in danger from foreign competition.

Black replied to Fullarton:—

"DEAR SIR,—

"I had the honour to receive your letter of the 27th February, but do not know of any manufactory as yet established in this country for preparing an alkali from common salt. A person here called Birnie has lately got a patent for an invention or process for that purpose, and has built a house in which it is to be carried on or tried, but has not yet begun to work. The nature of his process will appear from the specification of his patent which is on record. In another work in which vitriolic acid is made from sulphur, an alkali is prepared from the vitriolated tartar (sulfate de potasse) which is produced in both these processes. But it is plain that such alkali is the vegetable alkali and not the fossil, neither is it of a good quality.

"I have the honour to be, with the highest esteem,

"Your obdt. humble servant,

"J. BLACK."

Samuel Birnie's patent, alluded to by Black, runs as follows :—

“ A method of preparing and restoring the Calx of lead, after being used in extracting the mineral alkali from common salt, back into pig-lead. By an easier and less expensive process than any heretofore known, by which means a very great quantity of mineral alkali may be extracted in this country to advantage from common salt.”

The process was to calcine the lead ; to collect and melt the litharge ; the silver is thus separated. A mere allusion is made in the patent to the use of the litharge in producing alkali ; it is to be presumed that it was ground, mixed with salt, and heated ; on treatment with water, caustic soda would dissolve, and the lead would remain as chloride. The patent then goes on to describe the method of regenerating lead from its chloride, namely, by mixing it with one-sixteenth of its weight of lime or limestone and a sufficient amount of coal and furnacing it. The by-product is calcium chloride, “ a combination of lime with the marine acid, a marine salt with earthy base.”

Evidently neither Higgins, Fordyce, Keir, nor Collison had succeeded in establishing their processes on a large scale ; Black must have known of them ; and he must have preferred not to reveal their existence, or they must have ceased to manufacture. There is nothing to show whether Birnie's process proved a success ; it was probably superseded by Leblanc's. Anyhow, alkali was

not manufactured on a large scale in England until 1823, when Muspratt's works were started.

In May, 1790, Black made a long report to the Earl of Buchan on the best method of "burning" marl by the help of peat; and in April, 1791, he advised Sir John Sinclair on substances for smearing sheep. Sir John wanted to know whether some transparent varnish could not be substituted for the commonly used tar, which dirtied the wool; and Black defended tar on the ground of its having long been in use; he does not know whether brimstone has been tried. Hogs' lard containing a compound of mercury has been commended and defended by Sir Joseph Banks. In using tar it should be incorporated with fat. Arsenic has also been employed, a very small quantity being mixed with hogs' lard; Black thinks that it is likely to operate like quicksilver as a poison for vermin and as a remedy against scab.

Mr. Raspe consulted Black in November, 1791, about the best means of recovering silver from "horn-silver" (chloride) found in Cornwall; he had tried amalgamation unsuccessfully; also fusion in an iron pot with soda (carbonate). In Black's reply he points out that "luna cornea" will not amalgamate, either dry or wet. Margraaf has substituted spirit of sal ammoniac (solution of ammonia) for water, for it dissolves "luna cornea"; but he is sure that this would be far too expensive an agent. He himself has tried melting with common or aerated fossil alkali (carbonate of soda), but was disappointed, for although this process separates the silver, the latter remains disseminated through the mass in

small granules, and there is considerable loss ; but caustic alkali answered admirably. He also suggested quicklime as a substitute for caustic, but has not tried it himself.

The levying of the salt tax evidently gave some trouble. In October, 1793, Mr. Lockhart, Collector of Customs at Port-Glasgow, wrote to Black, asking for a definition of "bittern." Black's answer was : "The residue after crystallising salt. The Bittern does not yield any more common salt by further evaporation, but it contains some saline compounds which are useful in medicine." Mr. Lockhart then wrote : "The bushel of salt of 56 lbs. weight pays a duty of 1s. 6d. pr. bushel : suppose it was wished to draw a duty in proportion for bittern, what quantity of bittern would it require to have that duty of 1s. 6d. laid upon it ? " (This duty is £3 a ton.) Black refused to answer, for he says he did not wish to accept the responsibility ; to which Lockhart replied that any advice would be solely for his private information. Still Black would not advise ; but he determined the density of a sample of bittern and found that a gallon would weigh 69.55 lbs. "avverd."

These extracts give an idea of how Black occupied his time. He appeared to shirk correspondence, and in many cases it must have been somewhat exacting. In September, 1784, his old pupil Crell complained that a letter of his, written a year before, still remained unanswered ; he asked Black to inform him of any observations he had made, and also to keep him informed regarding the progress of discovery in Britain and America. In this we

see the journalist, for Crell had to procure "copy" for his *Annalen*. Crell also asked Black to procure a situation for a young friend of his, either in his laboratory or in a druggist's shop. He then goes on, as usual, to give an account, in his neat but minute handwriting, of various advances made on the Continent. Here is a sample: "M. Achard has succeeded in making little vessels for chemical uses of platina.—I possess a specimen of sandstone, remarkable in that it can be bent without being broken.—Dr. Storr has succeeded in converting siliceous earth into alum.—Mr. Scheele has detected in expressed oil and in animal fat a peculiar acid (?) which is very sweet; it is convertible into acid of sugar. (This must refer to the discovery of glycerine.)—Messrs. Wiegler & Scopoli have proved that the siliceous earth, obtained by distilling the 'acidum fluoris' takes its origin from the vitreous vessels used in distilling. You are no doubt acquainted with the acid of 'lapis ponderosus' (Tungsten, Swedish), detected by Scheele and Bergman; a disciple of the latter, named d'Elhujar, has with success reduced it by Phlogiston; he got a metal, the heaviest of all, except gold and platina, of the spec. gravit. 16:1, not dissoluble in any acid, and only corroded by Aq. Reg.—a very astonishing fact.—I should be exceedingly obliged to you, if by your proper occasion, you would be so kind as send me some specimens of the ∇ ponderosa Δ ata, proper still only to your country (strontia)."

Crell, poor fellow, still got no replies to his letters; for he wrote again in March, 1785, complaining that the letter he wrote six months back had not been answered.

He again begs a situation for the deserving young man, Sievers, who knows German, English, French, and Latin. He again describes flexible sandstone ; it mainly consists of siliceous earth ; Klaproth finds in it $96\frac{1}{2}$ siliceous earth, $2\frac{1}{2}$ argill, and 1 iron

As there is no draft of an answer to this letter, and as Crell's letters cease at that date, it is to be presumed that he gave Black up as hopeless.

Black's lectures were attended not merely by students, but also by the "virtuosi" of Edinburgh ; he succeeded in raising great interest in the science of the day. Whether he was responsible for the foundation of a Chemical Society I cannot ascertain ; but among his papers there occurs a list, of which only the date, 1785, is in his handwriting, entitled "List of the Members of the Chemical Society." This may have been a society of persons residing in Edinburgh interested in Chemistry, but is more likely to have been a general society ; the grandfather of the writer was the President of a Chemical Society in Glasgow, founded in 1798 ; the Chemical Society of London did not come into existence until 1841. It may be of interest to reproduce the names of the members of the Edinburgh Society, for it may chance that some one of their descendants may be in possession of some record of its proceedings and history.

John Webster
Wm. Scott
— Halliday
Jas. Forster
Sam. Black
Jno. Black

Hen. N. Ward
Morgan Deasy
H. Pache
Jno. Gay
Tho. McMorran
Adam Gillespy

J. Alderson
J. McElwaine
T. Gill
T. Willson
Frs. Montgomery
Thos. Swainson

Jas. Plumbe	Thos. Burnside	Archd. Webb
Wm. Johnston	Corn. Pyne	J. Crumbie
Thos. Clothier	J. Unthank	Geo. Majoribanks
Henry. Johnston	J. Barrow	T. Greig
Peter Gernon	J. Donovan	J. Parr
Robt. Ross	Saml. Macoy	Alex. Stevens
L. van Meurs	G. Tower	Wm. Symonds
(amteemann batavis)	J. Sedgwick	Thos. Beddoes
Hugh Brown	T. Skeete	J. Thompson
John Boyton	Wm. Robertson	G. Kirkaldie
Edw. Fairclough	J. Sprole	J. Carmichel
Bicker McDonald	Thos. Cooke	Nich. Elcock
F. Galley	Thos. Edgar	Richd. Gray
An. Mann	Guyton Jolly	J. Hayle

The only name that I can recognise is that of Dr. Thos. Beddoes ; the names themselves would indicate that their possessors belonged to all parts of the kingdom.

About this date Black paid a visit to London, for there is a list of a number of London addresses, and a bill for a "teapot and standish," bought at Chippendale's, 119 Fleet Street.

The price of platinum is now about £9 an ounce ; with that in mind it is interesting to learn that Dr. Luzuringa sent to Black 2 lbs. of platinum, along with a bill for £6 13s. 4d., which he objected to pay. He wrote to Luzuringa : "When I received the two Pounds which you procured for me, I received it as a present, & neither you, nor any other person gave me the least reason to think that I was to pay for it, nor was I at all inclined to buy platina. I consider it as a present from you, & it is not more than a sufficient acknowledgment for the extraordinary trouble I had in correcting your dissertation." On being reminded that he had promised to pay

for it, he sent the money by his brother ; in return Dr. Luzuringa sent him the diploma of the Academy of Madrid, and Black responded in the following Latin epistle :—

“ *Academiae Regiae Matritensis Literas quibus me in numerum Sociorum co-optatum esse didici tradendus mihi curavit D. Ignatius Luzuringa M.D. & nuper alumnus noster gratissimus. Te Vir doctissime precor Regiam Academiam certiolem facias me hanc benevolentiae suae testimonium cum reverentia animoque grato decipere. Et illustris Academiae labores ad publicam salutem promovendam designatos socia opera quantum potero adjuvandi percupidum esse. Vale !*

“ *Scribebam Edinburgi Scotorum die III^{ta} Mensis Julii Anno MDCCCLXXXIJ.*”

In this way an amicable understanding with Luzuringa was arrived at ; and on December 28th, 1787, Black wrote : “ I have not had leasure yet to undertake the set of experiments which I propose to myself on that metallic substance ; my time has hitherto been sufficiently filled up with business to prevent my enjoying such an amusement.”

In May, 1787, Adam Smith introduced to Black a certain Baron de Baert, who had travelled from Kiew to Astrakhan ; he was presented to Adam Smith by the Duc de Rochefoucault. Black must have been at considerable pains to entertain this distinguished stranger, for he received an effusive letter in French from him. The Baron, after leaving Edinburgh, made a tour through

Scotland, and received "la plus grande hospitalité." He was "un peu contrarié" in his passage to Mull, but had the most beautiful weather during his trip to "ikolm-kill et Staffe." He must have been a favourite among the Edinburgh cronies, for Black replied warmly, also in French, and sent him kind regards from Dr. Hutton and Dr. Smith.

CHAPTER VII

BLACK and Hutton were most intimate friends ; every afternoon was passed together, and many evenings. It was with Black that Hutton discussed his theories of geology ; and John Playfair, the Professor of Mathematics in the University, and the biographer of Hutton, says : “ There was in these two excellent men that similarity of disposition which must be the foundation of all friendship, and at the same time, that degree of diversity, which seems necessary to give to friends the highest relish for the society of one another.

“ They both cultivated nearly the same branches of physics, and entertained concerning them nearly the same opinions. They were both formed with a taste for what is beautiful and great in science ; with minds inventive, and fertile in new combinations. Both possessed manners of the most genuine simplicity, and in every action discovered the sincerity and candour of their dispositions ; yet they were in many things extremely dissimilar. Ardour, and even enthusiasm in the pursuit of science, great rapidity of thought, and much animation, distinguished Dr. Hutton on all occasions. Great caution in his reasonings, and a coolness of head that even approached to indifference, were characteristic

of Dr. Black. On attending to their conversation, and the way in which they treated any question of science or philosophy, one would say that Dr. Black dreaded nothing so much as error, and that Dr. Hutton dreaded nothing so much as ignorance ; that the one was always afraid of going beyond the truth, and the other of not reaching it. The curiosity of the latter was by much the most easily awakened, and its impulse most powerful and imperious. With the former, it was a desire which he could suspend and lay asleep for a time ; with the other, it was an appetite that might be satisfied for a moment, but was sure to be quickly renewed. Even the simplicity of manner which was possessed by both these philosophers was by no means the same. That of Dr. Black was correct, respecting at all times the prejudices and fashions of the world ; that of Dr. Hutton was more careless, and was often found in direct collision with both.

“ From these diversities, their society was infinitely pleasing, both to themselves and those about them. Each had something to give which the other was in want of. Dr. Black derived great amusement from the vivacity of his friend, the sallies of his wit, the glow and original turn of his expression ; and that calmness and serenity of mind which, even in a man of genius, may border on languor or monotony, received a pleasing impulse by sympathy with more powerful emotions.

“ On the other hand, the coolness of Dr. Black, the judiciousness and solidity of his reflections, served to temper the zeal and restrain the impetuosity of Dr. Hutton. In every material point of philosophy they perfectly

agreed. The theory of the earth had been a subject of discussion with them for many years, and Dr. Black subscribed entirely to the system of his friend. In science, nothing certainly is due to authority, except a careful examination of the opinions which it supports. It is not meant to claim any more than this in favour of the Huttonian Geology ; but they who reject that system, without examination, would do well to consider that it had the entire and unqualified approbation of one of the coolest and soundest reasoners, of which the present age furnishes any example."

It may be recorded here that Dr. Hutton was born in 1726 ; that he was educated at Edinburgh High School and University ; that after relinquishing the study of Law for that of Medicine, he graduated at Leyden in 1749. On returning to Edinburgh he did not pursue the career of a medical man, but entered into partnership with a Mr. James Davie, who started the manufacture of sal ammoniac (ammonium chloride) in Edinburgh. At the beginning, however, Hutton studied farming in Norfolk ; and this turned his attention to the subject for which his name will always remain famous, the study of geology. In 1754 he returned to Scotland and superintended a farm in Berwickshire, which he had inherited ; there he resided until 1768 ; but in 1765 he took active part with Mr. Davie in the management of their works. It was probably in 1765 that he became intimate with Black.

A tale is told in *Kay's Portraits* of Black and Hutton,

who were almost inseparable cronies. Having had a disquisition as to the waste of food, it occurred to them that while testaceous marine animals were much esteemed as an article of diet, those of the land were neglected; they resolved to put their views in practice, and having collected a number of snails, they had them cooked, and sat down to the banquet. Each began to eat very gingerly; neither liked to confess his true feelings to the other. "Dr. Black at length broke the ice, but in a delicate manner, as if to sound the opinion of his messmate: 'Doctor,' he said, in his precise and quiet manner, 'Doctor, do you not think that they taste a little—a very little queer?'—'Queer? D——d queer! tak them awa', tak them awa'!" vociferated Dr. Hutton, starting up from the table, and giving vent to his feelings of abhorrence."

When Black was elected Foreign Member of the Imperial Academy of Sciences of St. Petersburg, the Director, the Princess of Dashkow, who, it will be remembered, nominated Black for the Academy, wrote shortly after, in February, 1783, asking him to correspond with the Academy. Her words were: "Nobody better than you, whose abilities are known in all Europe, could better add a lustre to it." But he never appears to have done so. However, he must have thought that he had an opportunity to make known his friend Hutton's views in Russia; for in August, 1787, he wrote a long letter to the Princess. After referring to the retirement of Dr. Blair, Professor of Rhetoric, he alluded to Professor Dugald Stewart, then holding the Chair of Philosophy.

He then proceeded : " Dr. Hutton has assisted in making a catalogue of your beautiful collection of Derbyshire fossils. He has published a Theory of the Earth, which your Excellency may perhaps have a curiosity to know something of. I shall here give the general principles of it.

" There are two grand operations going on perpetually in Nature. One of these is the gradual and slow demolition of the elevated parts of the Earth's surface by the action of air, water, & frost ; by the repeated impressions of these agents the hardest Rocks and Mountains are slowly moldered down into Rubbish and dust. The materials are carried down into the Valleys by Torrents, Brooks, and Rivers, and are first deposited by the rivers during their course towards the sea, and thus form extensive and fertile plains, and afterwards are carried into the ocean by the same rivers which are constantly changing their beds and washing away a part of the soil, especially when they are swelled by floods. When this matter is brought down to the ocean or other large collections of water, wherever there is not sufficient current to keep it in motion, it is deposited at the bottom and forms new stratified matter. This operation is going on perpetually, and has produced so much effect that every elevated part of the surface of the Earth which we now see was once covered with other matter to a great depth. Were it to go on without being counteracted, the inequalities of the Earth's surface would be levelled in the course of time to a perfect plain, and mostly covered up by the sea or by collections of stagnating water. But there is a Remedy in Nature to prevent such



"THE PHILOSOPHERS": BLACK AND HUTTON.

From Kay's portraits.

a great change in the constitution of the Globe. There is also another cause acting as constantly to prepare new rocks and mountains, or as Dr. Hutton expresses it, 'new Land, or new worlds' in place of those which we see at present wearing down by time, and in place of many others which have existed, and have been demolished before them.

" This other cause is subterranean fire, the agency of which, tho' not so obvious, can be demonstrated to produce its effects constantly during very long periods of time under a great many parts of the surface of the Globe. This is evident from the hot springs and Vulcanic mountains and Islands, some of them burning, some extinguished, which occur in such a multitude of different places; besides a number of stones and rocks found everywhere, and which bear so exact a resemblance to the productions of subterranean fire found near Vulcanoes that natural historians have ventured to declare they must have been produced in a similar manner. The extensive agency of subterranean fire appears also from the history of Earthquakes, which prove that those fires exist at a greater depth, and have very extensive communications. The Earthquakes which within these very few years desolated Calabria shook a circular extent of the Earth's surface 144 Italian miles in diameter; the place from which the elastic matter exerted its force could not therefore be much less than 70 miles below the surface; but supposing it to be only 60 miles, the pressure to which it was exposed is enormous, and must have exceeded the pressure of the atmosphere at the

surface of the earth more than 100,000 times, viz^t :— 5 miles depth of air equally dense with the air at the surface of the Earth would have a pressure equal to that of the atmosphere; 5 miles of water would press 850 times as much, = 4250 atmospheres¹; 5 miles of earth and stone $2\frac{1}{2}$ times as much as the water, = 10,625 atmospheres; 50 miles of do 106,250 atmospheres. (The Italian mile is to the English as 10 to 12.)

The Earthquake which destroyed Lisbon affected the whole Island of Britain and the Islands of the West Indies. At what an enormous depth below the sea, must the fires and communications been situated by which such an effect could be produced! At such depths do these fires act in silence and darkness during successions of centuries, and under the pressure of the immense load of incumbent earth and water. Their most general effect is to consolidate and harden into stone of different kinds the material of former lands, which have long since been carried into the ocean, and deposited at the bottom of it in the form of regular but loose stratified matter; the strata of sand are hardened into sandstone. Those which contain clay mixed with the other materials are formed into Schistus's of different kinds. Collections of shells and corals which are formed at the bottom of the sea and afterwards covered with stratified matter, are consolidated into limestones and marbles; while the collections of vegetable inflammable matter, of which great quantities are also carried into the sea, by many

¹ This should evidently be 850 atmospheres; and the pressure of the earth should therefore be 21,250 atmospheres.

rivers, are compacted and indurated into strata of pit-coal. It is also evident that the fires must act with all the different degrees of force; a great part of the materials upon which they act must be situated beyond the reach of their greatest power, and must therefore suffer but little change; others receive so much heat as to be softened by it and made to approach to a state of fusion, and afterwards, when the heat leaves them, become dense and hard; and are otherways changed in many respects, tho' they still retain some marks of their stratified texture. Others, again, which are penetrated by a more intense heat, are actually melted, and form many of the rocks and stones in which all appearance of stratified arrangement is entirely obliterated. Some part of the melted substances is occasionally thrown out on the surface of the Globe in the eruptions of Vulcano's. But it must also necessarily happen that the same explosive power by which it is thrown out must force great quantities of it laterally in different directions among the strata which are at a great depth, and, by its accumulation in some places, must raise these strata and all the materials incumbent on them far above their former level; and occasion those bendings, fractures, erections, and dislocations of them, which come into our view after an immeasurable lapse of time, during which the materials which covered them have been gradually demolished and carried away.

“ While all this goes on at such an immense depth, and under such an enormous pressure of incumbent materials, products arise and combinations are formed

which we would in vain attempt to imitate at the surface of the earth. Water, and even air, enter into the composition of many hard stones which appear to have been softened, and even melted, by a strong heat. Water in drops is sometimes found included in cavities of agates, crystals, and other stones, without our perceiving the smallest communication between these cavities and the outside ; and there is a small quantity of water in the composition of the greater number of stones and mineral substances. There is reason also to think that heat, acting in the manner and with the circumstances above described, produces liquefactions of certain bodies, the fusion of which in other circumstances and by other means is extremely difficult or impossible ; such as the fusion of calcareous matter, and without separation of the fixed air. Perhaps they receive also into their composition a great quantity of latent heat, or of the electrical fluid, or of other subtile principles of a fugitive nature, which quit these bodies when relieved from the great pressure and surrounding heat. The example of Quartz or siliceous matter gives reason to form this opinion. Tho' at the surface of the earth, it is extremely infusible, we find in many specimens that it has taken the impression of crystals of schorl, in others from masses of Felspar, and in others from crystallised native silver, which shows that it was once more easily melted or softened than any of these bodies, or that it remained soft after they were congealed.

“ We find also that it has often penetrated wood or chalk or limestone or shells in a manner which shows that

it must have had a great degree of fluidity and tenuity, and have been in a state totally different from that in which we find it in those parts of the globe which are within our reach.

“ Dr. Hutton is of opinion that granite is one of those stones which have been melted by subterranean fire at a great depth, and that the grains of different matter of which it is composed have been formed in most cases by a spontaneous segregation or crystallisation in consequence of fusions & of an exceedingly slow refrigeration. The mountains of granite therefore have been accumulated in the places in which they are found by explosive protrusions of the melted matter in a lateral direction at a great depth ; and in such quantity as to have raised the stratified matter which was superincumbent ; & in many cases to have burst through a number of these strata. This idea agrees very well with the Phænomena observed by Mr de Saussure in his instructive *Voyages dans les Alpes* ; and it agrees with what Dr. Hutton had seen in examining the Granite Mountains of this country. It is improper to call them primary mountains, and the elevated strata which appear inclined towards them or resting on their sides, the secondary mountains. It is certain, by the plainest proofs, that the stratified matter which is called secondary, or which is supposed to have been brought together at a later period than the accumulation of granite, was in reality pre-existent to these in the greater number of cases.

“ In this system of Dr. Hutton's there is a grandeur and sublimity by which it far surpasses any that has been

offered. The boundless pre-existence of time & of the operations of Nature which he brings into our view ; the depth and extent to which his imagination has explored the action of fire in the internal parts of the Earth, strike us with astonishment. And when we consider the view which he gives us of a great river such as that of the Amazons, descending in a thousand streams from the high centre of the Andes, and forming those immense and level plains thro' which it flows in the greater part of its course, the mind is expanded in contemplating so great an Idea, and the length of time which the change thus imagined (I may say demonstrated) must have required ; the short-lived bustle of Man's remotest reach of History or Tradition, or of the inquisitive Antiquarian appear as nothing when compared with an object so great.

“Nor has this system this merit alone. It is founded on the efficacy of powers which we see actually existing, and daily producing similar effects ; and it is supported by innumerable facts observed in consequence of an accurate and judicious study of fossils for a great number of years. Dr. Hutton had formed this system or the principal parts of it more than 20 years ago : & he has found reason to be more & more confirmed in it by the study of fossils ever since that time. Other authors have observed a great part of the phænomena on which this system is built, and have perceived some of the truths deducible from them ; but none has perceived them in such a comprehensive manner, or employed them so ably to explain the whole of these subjects. The paper



DR. ADAM SMITH.
(THE AUTHOR OF "THE WEALTH OF NATIONS").
From Kay's portraits.

he has published in our *Transactions* is but a specimen ; he is preparing a larger work.

“ I perceive instead of writing a letter, I have wrote a discourse. Your Highness must forgive a little pedantry. To confess the truth, I had been thinking of a lecture on this subject for next winter, and I perceive that my lecturing ideas have escaped from me in writing my letter.

“ EDINBURGH, 27th August, 1787.”

This is really a résumé of two papers published by Hutton in the *Transactions of the Royal Society of Edinburgh* ; they were read before the Society on March 7th and April 4th, 1785. In Playfair's life of Hutton, we are told that this paper was attacked both at home and abroad ; it was then revised, partly rewritten, fresh illustrations and additional facts were inserted, and it was published in two volumes, entitled *Theory of the Earth, with Proofs and Illustrations*, in 1795. When Hutton died, in 1797, he left the manuscript of a third volume, part of which has unfortunately been lost ; Chapters IV to IX, however, after having lain in the library of the Geological Society for many years, were published by the Society in 1899 ; they were edited by Sir Archibald Geikie. Hutton's friend and biographer, John Playfair, however, published in 1802 his *Illustrations of the Huttonian Theory*, and by it rendered Hutton's work more popular, for Playfair's style is a very attractive one. Professor Bonney holds the view that Hutton “ will always stand in the front rank of philosophic Geologists ;

he laid sure and strong the foundations on which Lyle and modern Geologists have built, and dispelled a host of phantasms. I suppose no man ever effected such a revolution in Geology as has been done by his teaching."

Black's medical practice in Edinburgh was not a large one ; yet he appears never to have dropped it. From time to time he received letters on medical subjects from his numerous pupils, which are of little interest, and have not been reproduced here. One, however, is worth quoting ; it was from Dr. Eason, and is dated September, 1787. It says :—

" Dr. Smith's swinging cure for consumption has been tried here to no purpose ; we have had many consumptive complaints, and of such a nature that if the Doctor was to practise in Manchester, he would soon find that nothing less than swinging by the neck would cure the disease." To this Black replied in October : " The swinging has been tried here, and in some cases with good effect. Dr. Cullen informs me that he thinks one of his patients recovered his health by it, and another was relieved ; in this last one, it always diminished the frequency of the pulse."

On the last day of December, 1789, Black presented a memorial to the trustees of the funds collected for building the " New College," a building which still stands, pointing out that the Professor of Chemistry has strong claims for a house contiguous to his laboratory. Part of his statement is reproduced here, for it throws light on the conditions in which he carried on his work.

“ The Professor has, it is true, only one hour of teaching, but he must spend several hours every day in his laboratory in preparing for the experiments and operations of the next lecture, or finishing those already begun ; and as these operations often last ten, twelve, or twenty-four hours, or some of them several days, he is under the necessity of looking into it frequently during the day, and occasionally must be there early in the morning & late at night. Nor is this sort of labour confined to the session of the college ; he must have recourse to his laboratory at all times to carry on his studies, & qualify himself the better for the discharge of his duty. To study books, he can go to his library, but he must have recourse to his laboratory when he studies Nature, when he wishes to ascertain or discover new facts. To accommodate him properly therefore, he should have a house adjoining to his laboratory, with a private entry from the one to the other. And supposing the Professor of Chemistry should be allowed this advantage over the Professors of Medicine, he need not on this account be an object of envy ; his office is much more laborious than theirs who have only an hour of teaching daily ; it is also attended by considerable expence for fewel, furnaces, glass, and materials. The time he must necessarily bestow on his laboratory prevents him in some measure from courting the world, and giving those attentions which procure favour and employment as a physician, and he is often employed for the public or individuals in the examination of different substances or different questions which are objects of chemistry, and

many of which require much time and laborious attention for their investigation. On all these accounts he flatters himself that his proposal will not be thought unreasonable by those who will be pleased calmly to consider what is above set forth. But whatever may be thought of it, he has done his duty to the public and to his successors in office, by pointing out what is highly proper for promoting the improvement and facilitating the teaching of a useful science.

“JOSEPH BLACK.”

Black, however, did not succeed in convincing the trustees; no house was erected for the Professor of Chemistry. But it is an almost universal practice on the Continent that the occupants of Chemical Chairs shall have their laboratories in the same building and in connection with their houses of residence.

In this connection an interesting remark may be quoted, made incidentally by Black in replying to G. La Bruyère, of Ravenhead, near Prescott, as to how to prevent the formation of “larmes,” or drops, which attach themselves to the roof of a glass-furnace and fall into the glass-pots. The sentence is: “In Philosophical Enquiries, the principal or only object is *New Discoveries*; but in attempting improvements of Arts, the object in view is to make the art more profitable.” It is chiefly those who aim at the first object who are the means of establishing new industries.

The cost of living as a student in Edinburgh in those days can be gathered from a note to the Princess of

Dashkow, who wished to send three young Russians to attend Black's classes at her own expense. "The expences here for board and lodging for students who appear like gentlemen's sons, and are above 15 years of age, is from 10 to 12 pounds sterling per quarter, and they pay besides for the washing of their linnens, which is one guinea per quarter. To each Professor whose lectures they attend, they pay 3 guineas for the course, and they will need 4 to 5 guineas for buying books."

In June, 1788, James Watt sent two tea-urns, one as a present for Black, the other for Hutton. "I hope they will please; all I can say is that the workmanship is good, and the shape fashionable, which now-a-days constitutes beauty."

He goes on: "I have lately improved upon a hint I saw, and made a new instrument for measuring the specific gravities of liquids. It consists of a syphon of two equal legs with a tube joined to the bend of it, and a little valve in that pipe. One leg being immersed in water, and the other in the liquid to be examined, by sucking at the pipe, the liquors will both rise to columns proportioned to their specific gravities; and if it is about 13 inches long in the legs, you can easily judge to within 1-400th part of the specific gravity, or rather, of the longest column suspended."

In the October of this year Black visited Watt at Birmingham.

In May, 1789, the Marquis of Condorcet, "Secrétaire perpétuel" of the Académie des Sciences, informed Black that he had been elected an Associé étranger of the

Academy. Although the letter was naturally in French, Black's draft of his reply is in English ; there are many erasures and corrections.

“ EDINBURGH,

“ 15th July, 1789.

“ SIR,

“ I received your intimation of the honour which the Royal Academy of Sciences has conferred on me by electing me a foreign associate of their celebrated society. Have the goodness to assure them that this mark of their favour and regard has satisfied my highest ambition, and has added the sentiments of warm attachment and gratitude to the respect and admiration which I have always had for their eminent merit and rank among the learned and ingenious Societys of Europe. Allow me, Sir, to add that my satisfaction was much increased by the obliging manner in which you were pleased to communicate this event, and that I think myself fortunate in this opportunity to assure you of the high esteem with which I have the honour to be,

“ Sir, Your most humble and most obedient servant,

“ JOSEPH BLACK.”

It is interesting to find, in a letter addressed to Joseph Louis Macey, Orchard Street, London, in September, 1790, a letter from Black, docketed “ Description of my small beam.” In this letter Black describes his balance “ for weighing very small masses, such as the globules of metals produced by essays with the blowpipe.” “ The beam is a small piece of fir-wood, of the thickness of a

shilling, and a foot long, $\frac{3}{10}$ ths of an inch broad in the middle and $\frac{1}{2}$ - $\frac{1}{10}$ ths inch at each end, divided into 20 parts, 10 on each side of the middle, each division itself divided into halves and quarters. Across the middle is fixed by sealing-wax one of the finest needles procurable. The fulcrum is a bit of plate brass, which lies on the table ; the two ends are bent up to a right-angle so as to stand upright ; these two ends are ground at the same time on a hone, so that the extreme surfaces of them may be on the same plane. They rise above the table only $\frac{1}{2}$ - $\frac{1}{10}$ ths of an inch, so that the balance is very limited in its play. The weights are 1 globule of gold which weighs 1 grain, and 2 or 3 others which weigh $\frac{1}{10}$ th of a grain each, and also a number of rings of fine brass wire ; those I use happen to be $\frac{1}{30}$ th part of a grain each, but I have others much lighter. You will perceive that by means of these weights placed at different parts of the beam, I can learn the weight of any little mass, from 1 grain or a little more to the $\frac{1}{1200}$ th of a grain. Had I occasion to use a more delicate one, it would be easy to make it, by taking a much thinner and lighter slip of wood, and grinding the needle to give it an edge."

It is probable that much of Black's classic work was performed with such a home-made balance.

Another piece of apparatus, which has long ago come into general use, is carefully described in a note in Black's handwriting, under the title " Hydrometer or Peseliqueur employed by Pierre Jacques Papillon." It is exactly like an ordinary hydrometer, with a glass stem, graduated, however, in arbitrary degrees, with a bulb full of air, and

beneath the bulb a smaller bulb containing the requisite amount of mercury to make it float to the height desired.

Among the letters received is one from Dr. Lind, at Windsor, describing how to make "phosphorated lime" (calcium phosphide), by distilling phosphorus vapour over red-hot lime in an iron tube. It was "lately discovered by Dr. Pearson, and emits fire, when put into water"; this is due to the escape of phosphoretted hydrogen, contaminated with the vapour of the liquid phosphide, P^2H^4 . Dr. Lind also describes a copying-press which he has invented, and encloses a copy of the page on which the description is written; also a number of copies of silhouettes, very well done.

The last letter which has been preserved is one from Sir John Macpherson, who wrote from Broughton, near London. After describing the method of forging platina into vessels he goes on: "I met Mr. Proust at Segovia in Spain. He shewed my company and me many curious experiments, and finding I was from Great Britain, he asked me about you. When I mentioned my having the happiness of knowing you very well, he exclaimed 'Ah! c'est le Patriarche de la Chimie,' and he insisted on my charging myself with a volume of his works to be presented to you. If you wrote to him to the care of our Minister in Spain, you would make him, and what is more, his Royal Master (who is likewise a chymist) very happy."

Thus ends the correspondence of Joseph Black. I have endeavoured to extract from the numerous letters and

their replies matter of general interest, from the point of view of chemical theory, of the progress of manufactures, of the manners of the time, and of forming an idea of the life which Black led. It will have been seen that his life was an uneventful one, passed largely in doing his best to instruct his students and in helping forward the cause of science and industry by his help and advice. His lectures must have been full of inspiration.

His pupil, Henry Brougham, the statesman, portrays him in his *Philosophers of the time of George III* as "a person whose opinions on every subject were marked by calmness and sagacity, wholly free from both passion and prejudice, while affectation was only known to him from the comedies he might have read. His temper in all the circumstances of life was unruffled. . . . The soundness of his judgment on all matters, whether of literature or of a more ordinary description, was described by Adam Smith, who said, he 'had less nonsense in his head than any man living.' " Brougham, writing as an old man, said : "I love to linger over these recollections, and to dwell on the delight which I well remember thrilled me as I heard this illustrious sage detail the steps by which he made his discoveries, illustrating them with anecdotes sometimes recalled to his mind by the passages of the moment, and giving them demonstration by performing before us the many experiments which had revealed to him first the most important secrets of nature. Next to the delight of having actually stood by him when his victory was gained, we found the exquisite gratification of hearing him simply, most gracefully, in the calm

spirit of philosophy, with the most perfect modesty, recount his difficulties, and how they were overcome; open to us the steps by which he had successfully advanced from one part to another of his brilliant course; go over the same ground, as it were, in our presence, which he had for the first time trod so many long years before; hold up perhaps the very instruments he had then used, and act over again the same part before our eyes which had laid the deep and broad foundations of his imperishable renown. Not a little of this extreme interest certainly belonged to the accident that he had so long survived the period of his success—that we knew there sat in our presence the man now in his old age reposing under the laurels won in his early youth. But take it altogether, the effect was such as cannot well be conceived. I have heard the greatest understandings of the age giving forth their efforts in its most eloquent tongues—have heard the commanding periods of Pitt's majestic oratory—the vehemence of Fox's burning declamation—have followed the close compacted chain of Grant's pure reasoning—been carried away by the mingled fancy, epigram and argumentation of Plunket; but I should without hesitation prefer, for mere intellectual gratification (though aware how much of it is derived from association) to be once more allowed the privilege which I in those days enjoyed of being present while the first philosopher of his age was the historian of his own discoveries, and be an eye-witness of those experiments by which he had formerly made them, once more performed with his own hands."

Black spared no pains to make his lectures attractive and useful. He illustrated them by numerous experiments; Robison tells us that, "while he scorned the quackery of a showman, the simplicity, neatness, and elegance with which they were performed were truly admirable." And Brougham also praises his manipulation. "I have seen him," he writes, "pour boiling water or boiling acid from one vessel to another, from a vessel that had no spout into a tube, holding it at such a distance as made the stream's diameter small, and so vertical that not a drop was spilt." "The long table on which the different processes had been carried on was as clean at the end of the lecture as it had been before the apparatus was planted upon it. Not a drop of liquid, not a grain of dust remained."

It would serve little purpose here to enter fully into the contents of Black's lectures; they are of only historical value. As already remarked, they were edited by his friend and colleague, John Robison, in 1803; and on p. 39 a short statement has already been given showing how he regarded heat, as illustrating his own experimental work on latent heat. As Robison's work is now only to be found in libraries, it may, however, perhaps prove of interest if I give a short summary of the method in which this eminent teacher treated his subject.

Part I of Black's lectures was, as already remarked, taken up with the consideration of Heat. Part II is headed "General Effects of Mixture." After pointing out that such substances as oil and water will not mix, or unite,

he deals with slow and quiet union, such as that of salt with water ; then with instances where much heat is evolved, as in the mixture of vitriolic acid with water ; or much turbulence, as when vitriol is added to ammonia. He then distinguishes between suspension, as shown by a mixture of clay and water, and solution, and deals with saturated solutions. Freezing or evaporation will serve to separate the constituents of a solution ; but certain forms of union are to be decomposed only by the addition of a third body, as, for example, when "oleum tartari" (solution of potassium carbonate) is added to a solution of marble in the "marine acid" (hydrochloric acid) there is a copious precipitate of a matter identical with marble. He then discusses various theories by which an attempt has been made to account for chemical combination, and treats at length of "elective attractions."

Part III deals with Chemical Apparatus, including furnaces and fuels, and the various ways of applying heat. The next heading is "The Chemical History of Bodies" ; he classifies the various chemical substances in five classes : (1) the salts ; (2) the earths ; (3) the inflammable substances ; (4) the metals ; and (5) the waters. He apologises for not making a special class of gases ; but defends his choice by the plea that the gaseous state is merely due to the temperature to which bodies are exposed.

Under the division "Salts" he describes crystallisation ; and proceeds methodically through I, the alkaline salts, treating successively of the "Vegetable alkali" (potash), the "Fossil alkali" (soda), and the "Volatile

alkali" (ammonia). Genus II comprises "Acid salts." The "Fossil acids" are the "sulphuric or vitriolic, the nitric, and the muriatic acids." These are the "Mineral acids." Others, not so strong, are the "Acetous acid; the acid of tartar; and the sedative salt, or acid of borax." Under Genus III are comprised the "Compound or neutral salts"; "Vitriolated tartar," or potassium sulphate; Glauber's salt, or sodium sulphate; nitre, or saltpetre (potassium nitrate); and under this head gunpowder and oxygen are dealt with. Then come "Cubic nitre," or sodium nitrate; "Digestive salt," or potassium chloride; next, common salt; next, "Vitriolic ammoniac," or ammonium sulphate; and "Nitrous ammoniac," or the nitrate; and "Sal ammoniac," or the chloride. "Regenerated tartar," or potassium acetate, and the "Alkali Fossile Acetatum" or sodium acetate, and "Acetous ammoniac," or ammonium acetate, follow. Tartar (potassium tartrate) and borax complete the list. A table of synonyms, according to the new nomenclature of Lavoisier, is added, and with that the first volume ends.

The second volume begins with the heading "Chemical History, Class II, Earths." The earths are distinguished by insolubility, as a rule; those of them which are soluble, such as "calcareous earth, barytes, and strontian spar," form a transition between the salts and the earths. They are also characterised by non-inflammability, fixity in the fire, and their density is, as a rule, not greater than four times that of water. They are the chief constituents of the surface of the earth. Here Black interposes a

short treatise on Geology, based on the publications of his friend Hutton. He then classifies the earths into the alkaline or absorbent earths ; the plastic, argillaceous, or clayey earths ; the hard, siliceous, or flinty earths ; the fusible earths ; and the flexible earths. He describes alkaline earths under the species of calcareous earth and magnesia ; and then follows a long disquisition on "fixed air," its discovery, its properties, and its compounds ; the digression covers the discovery of oxygen and nitrogen, and a short description of gases in general.

The compounds of the alkaline earths with acids, comprising gypsum (calcium sulphate), fluor (calcium fluoride), "phosphat of lime," and "borat of lime" are then described ; and he proceeds to Section III, Barytes, and Section IV, Strontites.

Under Genus III, the plastic earths, alum is treated of. Genus IV, "Hard stoney bodies," contains crystal, chalcedony, quartz, agate, flint, and a fine loose earth, which may be called "silica limosa." Glass and porcelain are shortly described under this heading.

Genus IV comprises "fusible stones" ; these are : "Feldt spat" ; porphyry ; the "garnat" ; the stony matter called *schoerl* by German and *cockle* by English miners ; the "zeolite" ; lastly, "the lavas, basaltes, pumice, and other fusible matters which have evidently been thrown out of the bowels of the earth by volcanic fires and explosions." Genus VI, the flexible earths, contains two subdivisions, mica and amianthus, or asbestos. Magnesia is always a constituent of these.

After these sections follows an appendix on precious stones and gems.

Class III covers Inflammable or Combustible substances. They are: (1) Inflammable air; (2) Phosphorus; (3) Sulphur; (4) Charcoal; (5) Spirit of wine; (6) Oils; and (7) Bitumens.

Fire-damp is treated of under the first heading; also balloons. Cavendish's discovery of the composition of water and Lavoisier's deductions from his discovery complete the section.

Under "phosphorus," calcium phosphide and phosphuretted hydrogen are touched; and under "sulphur," sulphides and sulphuretted hydrogen. Then follows an appendix on *pyrophori*, or *phosphori*. Heading V contains a description of the manufacture of alcohol and of ether; also of "dulcified spirit of nitre," a mixture of ethyl nitrite and nitrate; also sugar, oxalic acid and its salts; and Section VI, oils, is divided into aromatic or essential oils, camphors, balsams and resins, caoutchouc, unctuous oils (with an account of soap), spermaceti and beeswax; the section closes with empyreumatic oils, pitch and tar. Under Section VI, bitumens, the origin, sources, and mining of coal are described.

Class IV consists of Metallic substances. After a general introduction, in which the properties of metals are defined, the oxidation of the metals, their solution in acids, and their relation to the salts is set forth; and they are then discussed in the following order: arsenic; "magnesium" (by this manganese is meant); iron; mercury; antimony; zinc; bismuth, or "tin-glass";

cobalt ; " niccolum " ; lead ; tin ; copper ; silver ; gold ; and lastly, platina or platinum. This classification is somewhat odd from a modern point of view ; for example, under " magnesium " (manganese), the preparation and properties of chlorine are described, and also potassium chlorate ; under the heading " Iron," Prussian blue, ink, and the metallurgy and medicinal virtues of iron are all gone into at length. Under the heading " Mercury," not only is oxygen again considered, but also the oxides of nitrogen ; and under the heading " Lead," the manufacture of flint glass.

The last section in the book deals with waters ; ordinary waters, mineral waters, and sea-water, with methods for their analysis.

The lectures in their printed form extend to over 1500 pages quarto ; Black was somewhat diffuse in treating his subject. The style is interesting, and a great amount of what may be called miscellaneous information was given. They were, no doubt, admirably adapted to attract and rivet the attention of a general audience, as well as to be useful to the students of medicine.

While in Edinburgh Black published two papers, the first communicated to the Royal Society, and published in the *Philosophical Transactions*, the other in the *Transactions of the Royal Society of Edinburgh*. The first is entitled " The Supposed Effect of Boiling Water, in disposing it to freeze more readily, ascertained by Experiments " ; in it he showed that while unboiled water, on being cooled below the freezing-point, may withstand a considerable reduction of temperature



JOSEPH BLACK.

From Kay's portraits

without freezing, boiled water always begins to freeze as soon as the temperature falls below the freezing-point. If unboiled water is stirred, however, it behaves like the other. His explanation was that the boiled water is constantly absorbing air, which disturbs it, and thus produces the same effect as stirring. His other paper dealt with "An Analysis of the Water of some Boiling Springs in Iceland"; the water was brought from the large geyser near Reikjavik by Sir J. Stanley. It was found to contain a considerable amount of silica in solution.

In such pursuits, lecturing to his students, preparing his lectures, attending to his correspondence, spending his afternoons in strolling with one or other of his friends, Adam Smith, David Hume, Adam Ferguson, John Home, Alexander Carlisle, Clerk of Eldon, and his brother Sir George, Roebuck, and James Hutton on the Meadows, or Bruntsfield Links, or towards Salisbury Crags; or in the evening at the "Oyster Club" or some other mild convivial entertainment, Black spent his uneventful life. Thomas Thomson says that Hutton was the only one to whom Black imparted all his speculations in science, and who knew all his literary labours; there was seldom a day on which the two friends did not meet.

To quote further from Thomson: "Towards the end of the eighteenth century, the infirmities of advanced life began to bear more heavily on his feeble constitution. Those hours of walking and gentle exercise, which had hitherto been necessary for his ease, were gradually curtailed. Company and conversation began to fatigue;

he went less abroad, and was visited only by his intimate friends. His duty at college became too heavy for him, and he got an assistant who took a share of the lectures, and relieved him from the fatigue of the experiments. The last course of lectures which he delivered was in the winter of 1796-7. After this, even lecturing was too much for his diminished strength, and he was obliged to absent himself from the class altogether ; but he still retained his usual affability of temper, and his habitual cheerfulness, and even to the very last was accustomed to walk out and take occasional exercise. As his strength declined, his constitution became more and more delicate. Every cold he caught occasioned some degree of spitting of blood ; yet he seemed to have this unfortunate disposition of body almost under command, so that he never allowed it to proceed far, or to occasion any distressing illness. He spun his thread of life to the very last fibre. He guarded against illness by restricting himself to an abstemious diet ; and he met his increasing infirmities with a proportional increase of attention and care, regulating his food and exercise by the measure of his strength. Thus he made the most of a feeble constitution, by preventing the access of disease from abroad, and enjoyed a state of health which was feeble, indeed, but scarcely interrupted ; as well as a mind undisturbed in the calm and cheerful use of its faculties. His only apprehension was that of a long-continued sick-bed—from the humane consideration of the trouble and distress that he might thus occasion to attending friends ; and never was such generous wish more completely gratified.

“ On the 10th of November, 1799, in the seventy-first year of his age, he expired without any convulsion, shock or stupor, to announce or retard the approach of death. Being at table with his usual fare, some bread, a few prunes, and a measured quantity of milk diluted with water, and having the cup in his hand when the last stroke of his pulse was to be given, he set it down on his knees, which were joined together, and kept it steady with his hand in the manner of a person perfectly at ease ; and in this attitude expired without spilling a drop, and without a writhe in his countenance ; as if an experiment had been required to show to his friends the facility with which he departed. His servant opened the door to tell him that someone had left his name ; but getting no answer, stepped about half-way to him ; and seeing him sitting in that easy posture, supporting his basin of milk with one hand, he thought that he had dropped asleep, which was sometimes wont to happen after meals. He went back and shut the door ; but before he got downstairs some anxiety, which he could not account for, made him return and look again at his master. Even then he was satisfied, after coming pretty near to him, and turned to go away ; but he again returned, and coming close up to him he found him without life. His very near neighbour, Mr. Benjamin Bell, the surgeon, was immediately sent for ; but nothing whatever could be done.”

Black left more money than anyone thought he could have acquired in the course of his career. His will was

a somewhat fantastic one ; he divided his property into ten thousand shares ; and he distributed it among numerous individuals in shares or fractions of shares according to his conception of their needs or deserts. He had the reputation of being somewhat parsimonious ; but Robison states that he knew of many instances where Black had risked large sums of money for his friends. The tale probably arose from his curious habit of weighing the guineas paid to him as fees by his pupils ; but this may have been a very necessary precaution, and merely a sign of his scrupulous exactness.

Black furnishes an example of what is not infrequent ; of a man doing his best work at an early age. In his case, the cessation of his originaive activity was due in great measure to his poor health ; but he had the satisfaction of being able to influence many young men by his lectures to continue the investigations which he had not sufficient energy to pursue. We live now in a more exacting age ; and yet few can be said to have made such a lasting impression on science as did Black by his fundamental experiments on chemical combination and on heat.

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